METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

NOVEMBER, 1935. VOL. XIII., No. 73.

Development in Roll Manufacture

ADAMITE ROLLS FOR ROLLING MILLS

Mr. F. C. T. Daniels, Chief Metallurgist, The Mackintosh-Hemphill Co., Pittsburgh, U.S.A.

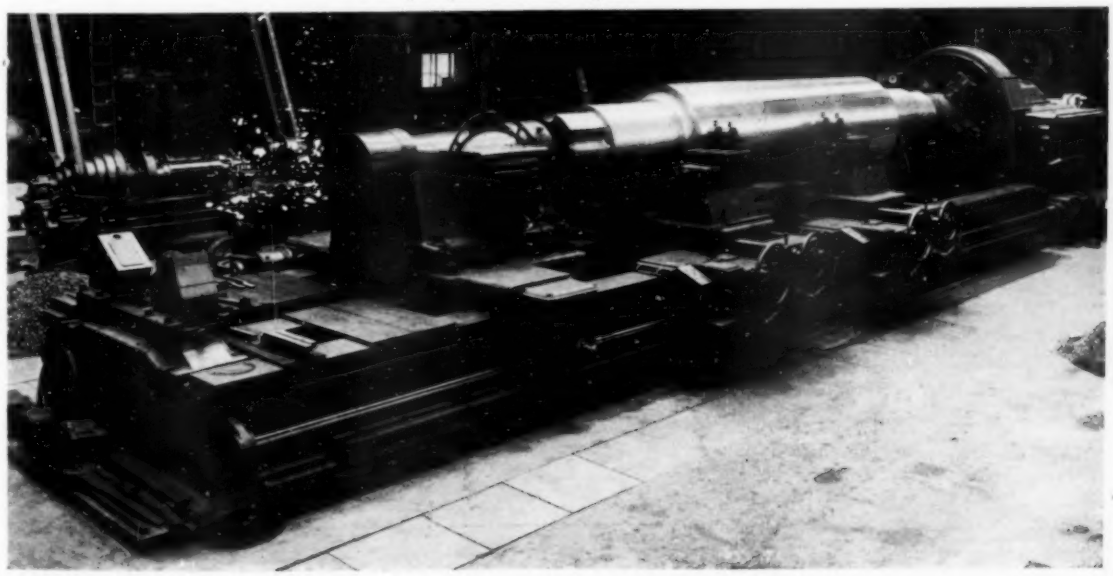
Mr. James Tennent, Managing Director, R. B. Tennent, Ltd., and Chairman of the Roll Makers' Association.

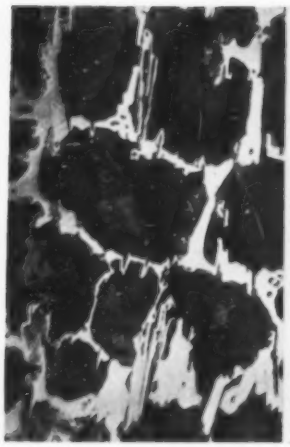
Economic conditions in the iron and steel industry necessitate high tonnage rolls, and roll manufacturers endeavour continually to meet this demand. Remarkable results in this respect have been achieved from the development of "Adamite" metal, which is claimed to have revolutionised the use of rolls for most purposes from cogging, through the various passes, to the finishers. "Adamite" rolls are now manufactured in Great Britain by R. B. Tennent, Ltd., and in this article the application is discussed and facilities provided for roll production described.

IT is doubtful whether any part of equipment in an iron and steel plant causes more controversy than rolls in the mill. Experience has shown that variations in the characteristics of rolls are not only necessary for hot and cold rolling but for practically every operation through the different stages of cogging, roughing, intermediate, and finishing passes, and modern steel-works practice demands a high tonnage output with the minimum of wear and breakage. In view of the loss resulting from excessive wear and breakages, mainly due to the speeding-up of modern mills, it is not surprising that manufacturers who specialise in roll production have given special attention to the materials employed and to the technique of roll production.

As is well known, the range of rolls used for many years embraces plain carbon steel, forged steel, cast-iron (grain) rolls, and cast-iron chilled rolls. The application of these types of rolls varies with the billets, sections, plates or sheets that have to be produced. Gradually, however, there has grown a demand for a better finish, a longer wearing life, and a bigger tonnage from rolls. To meet this demand, Messrs. R. B. Tennent, Ltd., are now producing

Chilled Plate Roll 48-in. diameter by 12 ft. 7 in. long on barrel in the 36-in. Craven lathe. The finished weight of this roll is 35¼ tons.



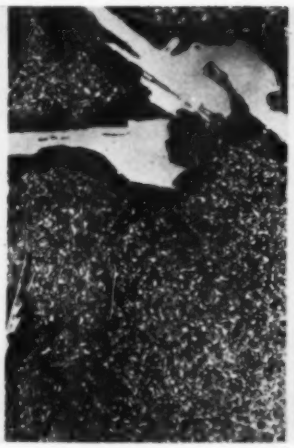


×330

Etched in nitric acid, showing the "as cast" structure.

×750

Etched in nitric acid. Shows the structure after heat-treatment to give maximum hardness.



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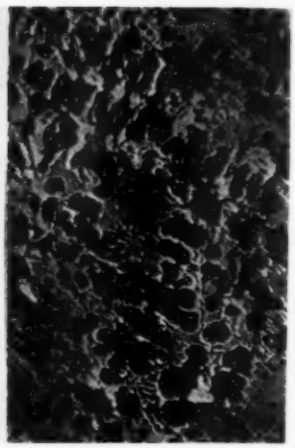
Etched in nitric acid. After heat-treatment to give optimum properties of hardness and toughness.



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Etched in nitric acid, shows the alloy with a hardness of 450 Brinell.

Some indication of the structure of "Adamite" may be gained from these photomicrographs.

rolls composed of an American alloy known as "Adamite." This development is the result of careful investigations of progress in roll manufacture, both at home and abroad, and is in line with the firm's practice of keeping abreast of the times. Founded in 1857 by the late Mr. R. B. Tennent, this firm has steadily grown, specialising mainly in all varieties of heavy iron and steel rolls, and the introduction of these new type alloy rolls to British users is a substantial step forward in meeting the demands of the industry.

"Adamite" Developments.

Developed and patented in America early in 1913, "Adamite" brought about what was practically a revolution in the use of rolls for nearly all purposes, except those for plate and sheet mills. Rolls produced from this alloy soon found favour, and remarkable record tonnage performances were early achieved in the various operations, from blooming mills to finishing shapes on small guide mills.

Casting the first "Adamite" Roll at Messrs. Tennent, Ltd. Finished weight of the roll was 20 tons.

Many manufacturing irregularities were experienced, and many wrong applications were made during the initial stages, but rapidly a sound manufacturing practice was evolved, and the proper gradation application developed which guaranteed a successful use of "Adamite."

Its success caused developments with similar materials, but with compositions just outside the limits of the patent. None, however, quite reached the success and wide application of "Adamite." With the outbreak of the World War more steel was demanded. To meet the demand, mills were overloaded, and the reductions per pass increased to such a point that the older types of rolls failed. It was then that "Adamite" first made a reputation, and in American practice to-day the "Adamite" roll is claimed to be standard practice. Its use is broad: the mildest grades do yeoman service in blooming and slabbing mills; intermediate grades are used for structural mill roughing, up through the intermediate and finishing stands. It is claimed that plain carbon steel, forged steel, or cast-iron (grain) rolls are not now used in America unless conditions do not warrant the use of a high tonnage roll.

Roll Composition of Two Types.

"Adamite" rolls are made in two types, one having a steel base and the other having a cast-iron base. All the grades of each type have the same low phosphorus and alloy content, but differ in the proportion of silicon and carbon, in furnace manipulation and in the subsequent heat-treatment procedures.

In the earlier days the "Adamite" rolls were mostly confined to the steel base of varying grades, and only a few "Adamite" iron base chill and grain rolls were made, mainly because the principal makers were steel roll-minded. The "Adamite" with cast-iron characteristics was originally produced for rolling mill guides, plugs, bending dies, and like wear-resisting parts. During the year 1922 the Mackintosh-Hemphill Co., of Pittsburgh, Pa., absorbed the Pittsburgh Iron and Steel Foundry Co., the originators of "Adamite," and they began at once to manufacture "Adamite" chill and grain rolls in large quantities.

The steel base "Adamite" rolls have the carbon wholly combined, and there is no visible graphite present. Their scleroscope hardness is varied from 32 to 55, depending upon the service in which they are to be used. The structure is entirely homogeneous, and it is of the same hardness throughout. Cogging mills are furnished with "Adamite"

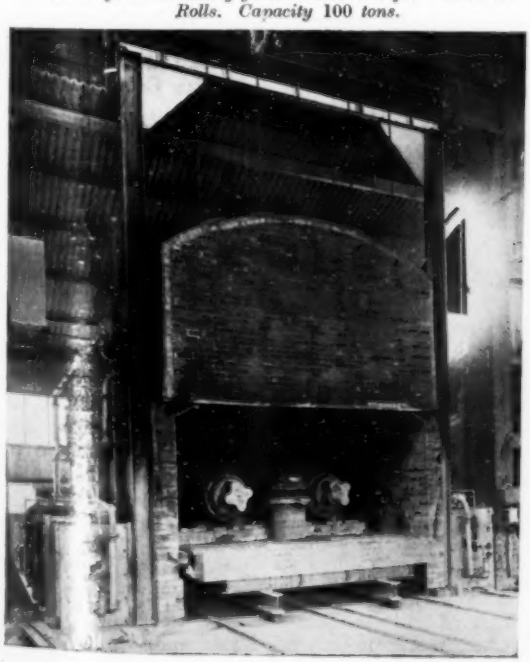
at 32 scleroscope ; structural roughers at 35 ; intermediates at 42 ; finishers at 48 ; while special service rolls, such as tube mill sizers, may be as hard as 55. This type of roll has avoided the necessity of using forged steel rolls for cogging mills in America. No forged steel rolls are used for the hot-rolling of steel in standard mills in that country. In the structural, merchant, and guide mills the " Adamite " type of roll has entirely superseded the older cast steel and sand iron (British " grain " or " metal ") rolls.

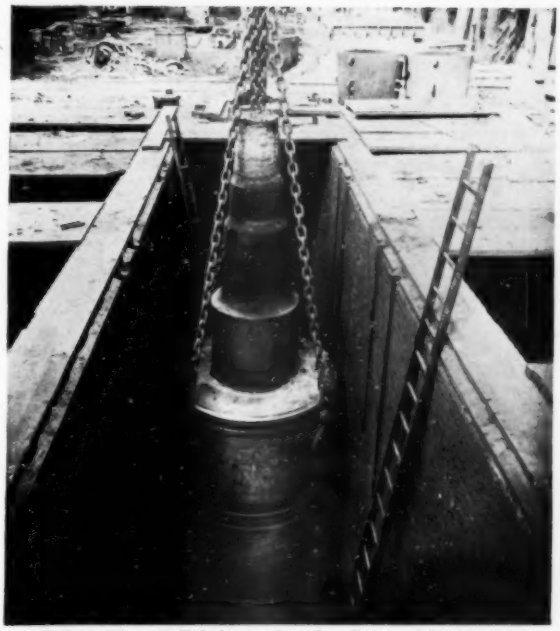
The iron base " Adamite " rolls are classified as " Adamite " chill and " Adamite " grain. They have as their base low phosphorus chilled cast-iron mixture alloyed with a proportion of nickel and chromium. " Adamite " chill roll characteristics differ from the ordinary chilled iron roll, as commonly known, in that there is no distinct line of demarcation between the hard outer surface and the grey iron central portion of the bodies. The one shades off very gradually into the other, as will be noted in the accompanying illustration, with a corresponding very gradual diminution of the hardness and wearing qualities. They are fully 30% stronger than chilled iron rolls, and even though they possess a good hard structure at great depths, they can be used in positions in which chilled iron would utterly fail.

" Adamite " chill rolls are used for flat work in bar, skelp and strip mills, and for leaders, ovals, and finishers in merchant and guide mills in the production of the smaller shapes. For this purpose they are an ideal roll to carry in stock, because deep passes may be cut into the material with only a slight variation of its hardness at the bottom of the grooves. Special precautions are taken during manufacture so that the free or uncombined carbon is present in a finely divided amorphous condition to ensure that the toughness and wear-resisting qualities are maintained at a maximum. The actual surface hardness is from 60 to 70 scleroscope for varying purposes, and a corresponding hardness to depths of 3 in. or more will be 50 to 60. The chilled iron roll used in Great Britain for the same purpose is about 55 to 60 scleroscope hardness on the chill surface, and therefore the real utility of the " Adamite " chill roll is readily seen.

The " Adamite " grain rolls are similar to the chill rolls in their outstanding properties. They are mostly used in the larger sizes, and have the collars and grooves cast close to shape. They find their principal use in billet mills, and strand and finishing stands of structural mills.

An oil-fired annealing furnace installed for " Adamite " Rolls. Capacity 100 tons.





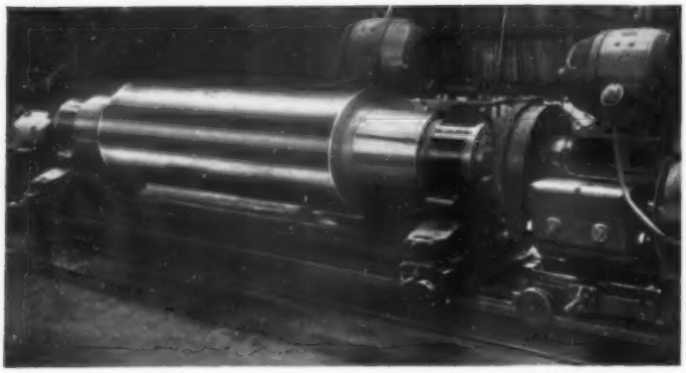
Chilled Plate Roll being stripped. Cast weight 42 tons.

Production of " Adamite " Rolls in Great Britain.

As a result of the reorganisation and modernisation of rolling mill plant during recent years, the demand for rolls which give a superior finish, longer wearing life, and increased tonnage, is just as pressing in Great Britain. In order that the industry could be supplied with rolls of this character, investigations were made on the Continent and also in the United States of America by Mr. James Tennent, managing director of Messrs. R. B. Tennent, Ltd. His object was to familiarise himself with roll technique abroad, and, if possible, to discover types that showed improved service under modern strenuous and exacting conditions. The claims of " Adamite " rolls proved of an outstanding character, and, in view of their wide use in America, arrangements have been made whereby Messrs. Tennent, Ltd., obtained manufacturing rights for British users.

It will be appreciated that much investigation has been necessary in the grading of the composition of " Adamite " and in the technique of roll manufacture to obtain the required properties and characteristics. In order that the results of these investigations could be applied, and a right technique employed, the arrangements included the services

Alloy steel Plate Roll during turning with Widia tipped tools. Finished weight 24 tons.



Chilled Plate Roll in grinding machine 42 in. dia. × 10 ft. long on barrel. Finished weight 26 tons.

of Mr. F. C. T. Daniels, on loan from the Mackintosh-Hemphill Co., of Pittsburgh. Mr. Daniels has been associated with the manufacture of "Adamite" rolls since their inception in America, and is recognised as one of the foremost metallurgists in that country. With his practical assistance, the grading of the composition and successful manufacturing methods have been defined and standardised to cover the wide range of applications for which these rolls have proved so successful. No experimental period therefore has been necessary, and Messrs. Tennent, Ltd., have started production with every confidence that the rolls correspond in quality with their American prototypes.

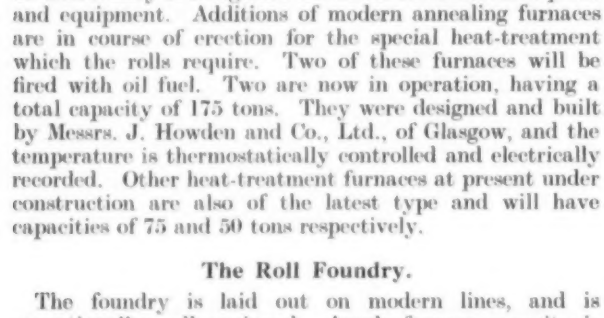
To manufacture "Adamite" rolls successfully, it has been necessary to reorganise the works and instal new plant and equipment. Additions of modern annealing furnaces are in course of erection for the special heat-treatment which the rolls require. Two of these furnaces will be fired with oil fuel. Two are now in operation, having a total capacity of 175 tons. They were designed and built by Messrs. J. Howden and Co., Ltd., of Glasgow, and the temperature is thermostatically controlled and electrically recorded. Other heat-treatment furnaces at present under construction are also of the latest type and will have capacities of 75 and 50 tons respectively.

The Roll Foundry.

The foundry is laid out on modern lines, and is exceptionally well equipped. Ample furnace capacity is provided. The steel base "Adamite" compositions are manufactured in a 50-ton open-hearth furnace, while the compositions for chill and grain rolls are made in modern reverberatory furnaces, of which there are four, one having a capacity of 40 tons, and this is claimed to be the largest in Great Britain. The melting plant also includes two cupolas.

An important feature in the production of "Adamite" rolls is the proper melting in the furnace, uniformity of the composition used, and most important of all, the temperature at which the metal is poured into the moulds. Each heat is controlled by the most modern pyrometers. The moulding box equipment and chills are consistent with a firm which has steadily grown since its inception, and which has specialised in the production of all kinds of steel and iron rolls, including the heaviest rolls ever cast in this country. The rolls are cast on end, the metal entering the moulds near the bottom in such a way that centrifugal action is given, so that the soundness of the roll surface is more likely to be assured.

Group of Pilger Rolls.



Brief mention of the heat-treatment plant has been made, but it is noteworthy that with "Adamite" rolls heat-treatment plays an all-important part in the success achieved. Theoretically, the whole mass of the roll should be heated uniformly throughout at the proper temperature, and should be maintained at that temperature for a period long enough to obtain the required grain structure and to relieve all internal stresses. With large diameter rolls, it is obviously necessary to heat gradually in order to make practice follow the theoretical requirements as closely as possible, and when the furnace eventually is raised to the necessary temperature it should be maintained at that temperature to enable the roll to become saturated.

The importance of slow heating is generally recognised, but the cooling of the roll is not less important. More than usual attention is given to this aspect of roll production by Messrs. Tennent, Ltd. They recognise that the influence of heat upon the quality of their products necessitates efficient methods of heating and cooling and careful control of heat-treating operations. The ideal sought in practice is more nearly attained by a proper combination of the furnace and the operative.

It is noteworthy that the whole control of the melting, casting, and heat-treatment of "Adamite" alloy is in the hands of the chief metallurgist and his laboratory staff.

The Machine Shop.

The demand for a high degree of accuracy in the products of the rolling mill is continually increasing. This accuracy is only possible when the rolls are accurate, and it is now possible to meet this demand. The most important requirements are true necks, true roll bodies, and, in sheet or plate rolls, accurate concavity or convexity of face to dimensions required. The machine-shop at the works under review is well equipped for dealing with the largest of rolls. It has been entirely reorganised, and includes, among others, one 36-in. and one 30-in. roll-turning lathes, specially designed and built by Messrs. Craven Brothers (Manchester), Ltd., to meet the requirements of Messrs. Tennents, Ltd. There is also installed a large roll-grinding machine by the Churchill Machine Tool Co., Ltd. The machines cover a wide range, and are capable of dealing with the widest range of rolls up to the largest required. The long experience of this firm and the steady progress achieved in roll production enable rolls to be produced to a very high degree of accuracy.

A Note to Mill Managers.

It will be appreciated that the adaption of "Adamite" rolls to a new application must be approached with intelligence. The material is made in a wide range of properties, and covers an equally wide range of utilities. In order to obtain the maximum values from the material and avoid possible mill failure, the mill manager and roll manufacturer should be called into consultation before a trial is made. Full facts should be available for consideration, including the type of rolls used previously, the degree of success, breakage or excessive wear, finishing qualites desired, tonnage expected, billet heating facilities, water conditions, passes, mill-speed, drive, etc., in fact any information which will assist the manufacturer to make full use of the outstanding properties of "Adamite" alloy.

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Alloy Steel Developments

DURING recent years there has been considerable progress in the application of alloy steels to industry. This is not only true of the special steels, which have been developed for particular purposes, and which for purposes of comparison are regarded as high-alloy steels, but also of low-alloy steels. It is generally recognised, however, that a considerable time-lag exists between the development of an alloy and its general application. Sometimes this time-lag may involve a decade, and it has been frequently said that industry should have the advantage of metallurgical developments with the minimum of delay. There are, of course, several factors which retard the rapid application of a new material; it is therefore a compliment to steelmakers that the merits of alloy steels have been appreciated, as indicated by the rapid progress in their use.

Despite the work carried out on alloy steels in various research laboratories, unless the user adopts the materials developed the manufacturer has little encouragement to improve his technique in order to supply better products. But the research worker is doing valuable work in assisting the user, as well as the manufacturer, by determining the field of usefulness for a particular alloy; this is especially true of the corrosion and heat-resisting alloys. One of the factors which influences the application of an unfamiliar material is the natural caution of the engineer or designer in using anything new. This caution is necessary in view of rather wild claims sometimes made for materials, and the manufacturer of a product genuinely developed must overcome the scepticism arising from unreliable claims. It is in this direction particularly that the research worker is assisting the progress in the use of alloy steels; he is supplying reliable evidence of the properties of a particular alloy which the intelligent engineer or designer can apply.

That the application of research to industry in general, in its relation to alloy steels, is bearing fruit, is indicated very clearly in the Report on Special Steels by Sir Robert Hadfield at the recent International Congress on Mining, Metallurgy and Applied Geology, in which he points out that while practical applications of special steels have been extending, scientific knowledge concerning them has also grown rapidly, and is laying the foundation of still further advances. In particular the study of precipitation hardening is mentioned, a phenomenon having its inception in the non ferrous alloy Duralumin, but since found to have much wider application extending to alloy steels of suitable compositions. As a practical means of conferring a measure of hardness by a heat-treatment less drastic then quenching, it would seem to have useful scope, especially since in many instances it can be applied to finished steel articles. The study of precipitation hardening has also done much to elucidate the old-standing problem of temper-brittleness in nickel-chromium and certain other high-tensile steels, and it is becoming clear that the two phenomena are intimately inter-connected in the sense that temper-brittleness appears to be associated with a particular stage of precipitation.

Another distinctive feature of modern research on alloy steels is the establishment as a class of what are known as the "ferritic" or "Alpha" steels, which have as their prototype silicon steel, just as manganese steel was the forerunner of the austenitic group of steels. These ferritic steels, through their special characteristics, have broadened the basis of the practical applications of alloying, since it is clear that the many different requirements of practice can better be served by having available not only steels which are amenable to heat-treatment, or are capable of taking carbon or carbides into solution, but also others which, as in the case with these ferritic steels, are negative in these respects.

The elements which, when added in sufficient amount to iron, confer these characteristics are many, and include among the more generally known alloying elements aluminium, chromium, molybdenum, phosphorus, silicon, titanium, tungsten and vanadium. Although several of these elements are at present comparatively expensive, the list provides good scope for research and investigation. Steels in this category containing about 16 to 18%, and in another case 30%, of chromium are in fact already usefully employed as corrosion- and heat-resisting steels in circumstances for which steels of the austenitic or pearlitic classes are not so suitable.

Notch brittleness, which is accentuated by grain growth, the only practical effect of heat-treatment, is in general a disability of these ferritic steels, although the possession of other desirable physical characteristics, as in the case of silicon steel, overrides this limitation. Reference to this fact leads to mention of an interesting and comparatively recent and significant discovery, in the remarkable effect of nitrogen in improving the toughness of ferritic-chromium steels, and in tending to inhibit crystalline growth in them. The full reason for this is for the present obscure, but will no doubt be made clear by further research.

The stupendous task of calculating the number of alloys which might be produced from all the varying combinations of the elements regarded as metals, of which mention is sometimes indiscreetly made, would be much greater if gaseous elements were also included. Actually, the whole question of gases in solution in ferrous alloys' and their possibilities in conferring properties, is one which seems to provide a fruitful line of research. There are many evidences that gaseous elements can, in certain circumstances, act in an alloying capacity in a similar way to solid elements.

Although practically all the binary ferrous alloys of a likely nature have now been explored, there still remains among the ternary and higher systems great possibilities, as witness the discoveries of new and remarkable permanent magnetic steels. Search of a systematic character necessarily becomes much more difficult as the number of added elements increases. In one modern alloy no less than eleven different elements are present. In these circumstances increased resort must be taken to simple pioneering, aided by such clues as present themselves. It is indeed a remarkable fact that great as has been the increase in our metallurgical knowledge, there is still ample work in front of the metallurgist to obtain full and adequate scientific understanding and knowledge of the principles of the alloying of iron with other elements, to say nothing of a similar position as regards non-ferrous alloys.

A feature of the improved knowledge of ferrous alloys acquired during the past decade has been the importance to an unsuspected degree of quite small amounts of impurities

on some of their properties. The work carried out at the National Physical Laboratory in Great Britain and elsewhere in redetermining the constitution and properties of certain of the binary ferrous-alloy systems, prepared from specially pure materials, is therefore of particular value in placing our knowledge of these systems on a sure scientific basis. Not the least valuable result of this work has been the production of non-ferrous elements such as chromium, manganese, and silicon in a highly pure form.

These examples suffice to show that research workers are not only endeavouring to provide new alloys possessing valuable characteristics, but are devoting much study to the perfection of those already developed with a view to improving quality. To acquire a fuller knowledge, fundamental aspects are being considered, and the requirements of the user are to-day as important as any other factor associated with metallurgical research. Owing to the rapid development of alloys, however, there is need for a greater technical knowledge of metals among users, if only to avoid the use of an alloy steel under conditions for which it is unsuited; obviously it is in the user's interest, as much as in the interests of the manufacturer, that an alloy steel should not be misused, otherwise the reputation of the material and of the firm supplying it is seriously damaged. This is not likely to happen when there is proper co-operation between technical men on both sides, and the progress in the use of alloy steels may be due to a better understanding between the metallurgist and the user.

The Action of Cold Water in Metal Corrosion

THE leading German technical and scientific associations, which united to form a joint council in connection with corrosion and its prevention, are holding the fifth annual Congress in Berlin on November 18–19. At the previous meetings corrosion was dealt with very broadly, a variety of papers being presented, but this time it has been decided to confine the attention of the Congress to one particular theme—"The corrosion of metallic materials of construction by cold water."

This subject is of vital importance in all branches of industry, but particularly is it of interest to gas and water engineers, and industries concerned with the disposal of effluents, more particularly from chemical works. A number of questions of technical and economic importance will be dealt with for the first time, the various speakers being experts on their particular subjects. In addition to the papers of more general interest, such as those dealing with the damage done by water corrosion, and the methods employed for its prevention, it is proposed to present papers dealing with rapid methods for the determination of rate of corrosion, and the standardisation of the laboratory equipment and methods of expressing the results of corrosion tests.

A number of well-known specialists from abroad are taking part in the discussion, among them being Professor Palmaer, from Stockholm, Prof. W. J. Mueller, from Vienna, and Prof. Kohlschütter, of Berne.

PUMPING 500 g.p.m. of bittern (the liquor in a salt works after the salt has crystallised out), averaging 23% calcium-chloride content, a Ni-Resist pump impeller has set up what is claimed to be a record for corrosion resistance at a large plant. The service obtained from pump impellers made of Ni-Resist, as well as that other metals previously used, is given in the following table:—

Ni-Resist (to date)	14 months.
Cast iron (total life)	9 ,,
Cast steel (total life)	8 ,,
Bronze (total life)	4 ,,

The engineer in charge of the plant estimates from the present condition of the impeller that the Ni-Resist will give a total service life of 30 months.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 22. "Utilisation of Creep Test Data in Engineering Design," by R. W. Bailey, B.Sc., A.M.I.Mech.E.

Dec. 13. "Damping Influences in Torsional Oscillation," by J. F. Shannon, Ph.D., A.M.I.Mech.E.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Dec. 5. Joint meeting with the local section of the Institute of Physics.

LONDON SECTION.

Dec. 12. "Die casting of Non-ferrous Metals," by N. D. G. Robertson.

NORTH EAST COAST SECTION.

Dec. 10. "The Manufacture and Uses of Powdered Metals," by J. C. Chaston, B.Sc., A.R.S.M.

SCOTTISH SECTION.

Dec. 16. "The Addition of Non-ferrous Metals to Cast Iron," by J. E. Hurst.

SHEFFIELD SECTION.

Dec. 13. "The Adhesion of Electro-deposited Nickel," by A. W. Hothersall, M.Sc.

SWANSEA SECTION.

Dec. 10. "Welding," by L. C. Percival, B.Sc.

MANCHESTER METALLURGICAL SOCIETY.

Dec. 4. "Notch Brittleness in Metals," by J. G. Docherty, D.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Dec. 6. "The Moulding of Light Castings by Means of Strickles," by T. W. Trayherne.

EAST MIDLANDS BRANCH.

Nov. 30. "Some Properties of Mould and Core Materials at High Temperatures," by F. Hudson.

Dec. 14. "A Comparison of Some Melting Furnaces in a Grey Foundry," by T. R. Twigger.

LANCASHIRE BRANCH.

Dec. 7. "The Dagenham Foundry of the Ford Motor Co., Ltd.," by V. C. Faulkner and J. N. Burns.

MIDDLESBROUGH BRANCH.

Dec. 13. Debate: "That the scientific aspect of the modern iron foundry is of greater value to the industry than the development of skilled labour." Proposed by D. Guthrie. Opposed by G. B. Taylor.

NEWCASTLE ON TYNE BRANCH.

Nov. 23. Joint meeting with the Coke Oven Managers' Association. "The Properties of Foundry Coke," by W. E. Mordecai.

Dec. 14. Discussion on "Strickle Moulding of Large Castings," by H. Fabre and H. Dubois.

SCOTTISH BRANCH.

Nov. 23. "Locomotive Castings" (at Edinburgh), by H. Lowe.

Dec. 14. "Metal Spraying."

WALES AND MONMOUTH BRANCH.

Dec. 6. "Electric Steel Foundry Practice" (at Llanelly), by R. J. Richardson.

Dec. 7. "The Control of the Properties of Pig Iron (at Cardiff), by J. E. Hurst.

INSTITUTE OF MARINE ENGINEERS.

Nov. 21. "Modern Methods of Welding," by R. S. Kennedy.

ELECTRO DEPOSITORS' TECHNICAL SOCIETY.

Nov. 20. Autumn Annual Meeting (London). Presidential address by E. A. Ollard, A.I.C., A.R.C.S.

Dec. 3. (Birmingham) "Methods of Heating Solutions in Electrodeposition," by J. Binns.

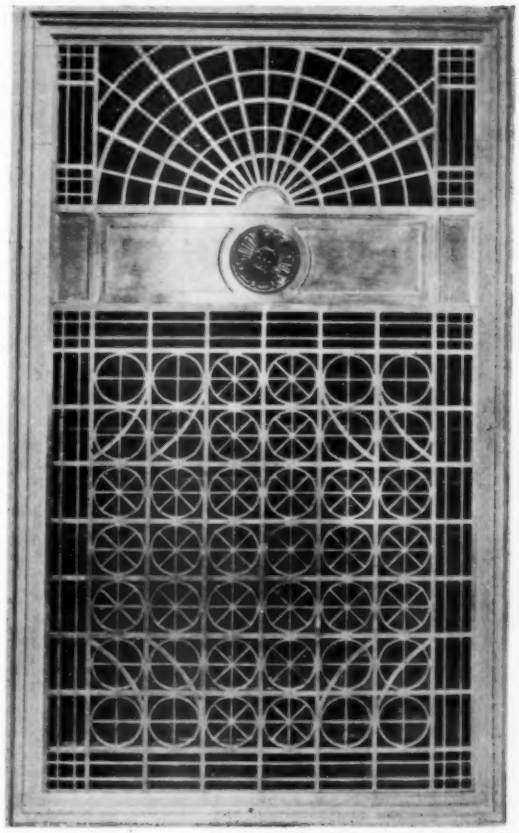
INSTITUTE OF WELDING.

Nov. 27. "Welding Jigs and Fixtures," by J. A. Ashworth (Manchester College of Technology).

In the Canadian pulp and paper industry large barking drums are used for scraping bark off the logs. Four gears, 13 ft. 9 in. in diameter and 9,500 lb. in weight, for driving these drums, have recently been made by the Montreal Foundry, Ltd., for Canadian Vickers, Ltd. The high torque required to set these heavy machines in motion puts a severe stress on the gears, and the impacts and vibration which are also encountered have led to the specification of a nickel alloy cast iron containing approximately 1.40% silicon, 0.75% nickel and 0.20% chromium.

Metals and Alloys for Internal Architectural Purposes

Metals have been used for decorative purposes since ancient times, and their use in architecture has long been appreciated; during recent years, however, metallurgical developments have facilitated the use of metals to an even greater extent. Quite a wide range of metals and alloys are available for this purpose, and in this article some of their important characteristics are discussed.



By courtesy of Messrs. Garton & Thorne Ltd.
Bronze Grille at Paddington Town Hall.

LONG before the Christian era copper was used extensively in architecture as well as for ornaments and household utensils. With the development of copper alloys the application of copper increased. The Romans, for instance, made considerable use of copper and bronze, not only for statues and objects of art, but for vessels, furniture, domestic articles, and a variety of architectural purposes. Since the days of the Romans the important use of bronze in architectural applications has been for ornamental doors and gates. Of the earlier examples not many are now in existence, the bronze doors of the Pantheon, which were erected by the Emperor Hadrian when the building was restored about A.D. 124, are said to be the only ones remaining *in situ*.

Few examples of early bronze doors or gates exist in England, and probably the oldest are the gates of Henry VII Chapel in Westminster Abbey, which were the work of Torrigiano, and date from the beginning of the 16th century. Copper and bronze have also been used in the past for such architectural purposes as railings and grilles. One early example of a protective grille, made of pierced copper sheet, which dates possibly from the 5th or 6th century, is to be found in the Church of the Nativity at Bethlehem, while a particularly beautiful example of a somewhat later bronze grille, dating from the 15th century, can be seen in the Chapel of the Sacred Girdle in the Cathedral of Prato. To-day not only is bronze used very extensively for such purposes, but the newer materials and alloys contribute in a large measure.

Architectural Bronzes.

Modern design and construction almost invariably demands some kind of architectural metal work to form a finish to either the exterior or the interior of a building. The growing use of steel framings associated with reinforced concrete render even more desirable the use of some kind of architectural metal work. The applications are extremely widespread, for not only are bronze casements, framings, doors, and other similar parts made in such materials, but in addition thereto the interior furnishings of a building may be rendered much more impressive through the judicious use of architectural bronze for such purposes as handrails, door-jambs, mouldings, screens, etc.

In the field of shop construction, architectural metal-work has long been in use, and whilst in some cases a complete scheme of decoration employing bronze has been adopted, in other instances the use of bronze showcases or a complete bronze shop-front has been associated with other forms of interior decoration, producing effects which afford considerable artistic satisfaction.

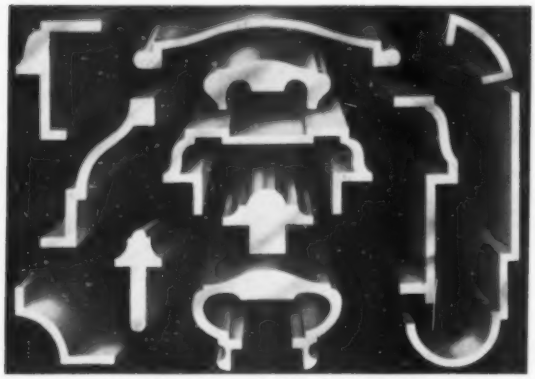
Some care must naturally be taken in selecting a metal for architectural purposes, because, whilst the primary consideration is that it shall be capable of withstanding the ravages of atmospheric corrosion, it must at the same time permit of being worked readily to the desired shape, possess a relatively high strength, and be of a pleasing colour. From the æsthetic point of view, the colour is probably the most important feature, and the garish appearance of brass is generally avoided in a scheme of architectural decoration.

Bronzes possessing these qualities are made by I.C.I. Metals, Ltd., McKechnie Bros., Ltd., the Delta Metal Co., Ltd., and the Manganese Bronze and Brass Co., Ltd. They are manufactured especially for architectural work, and possess those properties which ensure the necessary strength and corrosive resistance. The latter characteristic is an important feature, especially for external work. These bronzes are used successfully for all descriptions of interior art metal work, including gates, grilles, balustrades, hand-railing, panels, columns, lift gates and surrounds, lamps, signs, and, in part, all kinds of ornamental work. In every instance the naturally bronze colour of these alloys may be obtained simply by the action of the atmosphere; on the other hand, they may be buffed bright and retained in that condition or toned by any of the processes employed by art metal workers.

The architectural bronzes are easily worked, machined, drilled, cut, mitred, etc., and are readily jointed either by soldering or by welding. They are obtainable in a wide variety of forms. Extruded sections of almost every conceivable shape can be obtained, and it is noteworthy that, with modern manufacturing technique, the sharpness of outline obtainable in the extruded form renders this particular feature not the least desirable of their many qualities.

Nickel Bronzes.

Although the various "brown" bronzes are widely used, a "white"-metal finish is becoming more popular, and the nickel-silver alloys or "silver bronzes" are extensively employed in schemes of architectural decoration, either



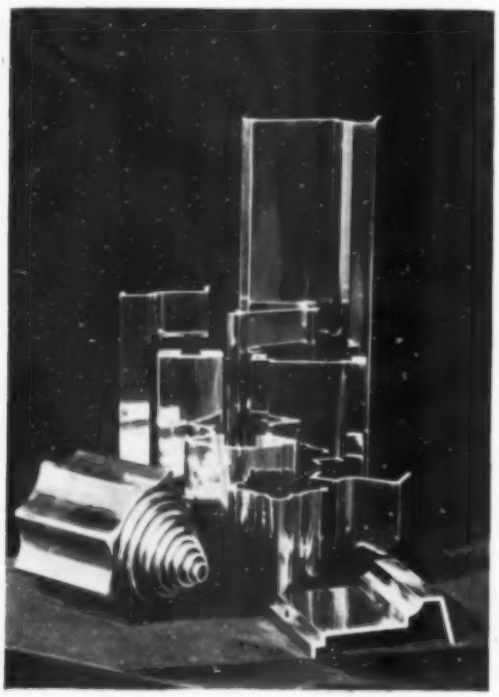
Examples of extruded sections in Delta bronze for architectural purposes.

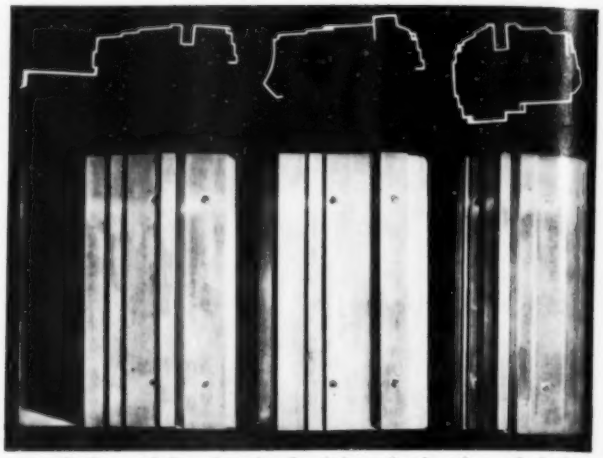
alone or in conjunction with other bronzes. These alloys consist essentially of copper, zinc, and nickel, the nickel content varying up to 18%, and depending upon the requirements of colour, resistance to corrosion, intricacy of section, and cost. A very pleasing range of colours is obtainable in these alloys, from a soft whiteness, with higher nickel contents, to a pale yellow, in alloys containing the smaller proportions of nickel. It is thus possible to obtain sections which will harmonise with any colour, and in conjunction with other alloys, such as the bronzes, to build up a colour scheme entirely in metals.

The pleasing appearance of these nickel-silver alloys is inherent in the metal. They are in no way dependent upon a thin coating or plating which may become damaged in use or even during erection. They take a very high polish or may be given the satin or sand-blasted finishes so frequently employed in architectural and other decorative schemes to-day.

The fact that these alloys can be extruded renders them available in a wide range of sections—from simple rounds, squares, and hexagons, to complicated interlocking shapes for pilasters and cornices. Those which are used for architectural purposes are marketed under various trade names as "White Metal," "Silver Bronze," and "Nickel Bronze," as well as being known as nickel silver. No

A collection of extruded sections in the C.94 Architectural Bronze.





Standard extruded sections in aluminium showing the method of interlocking that is adopted.

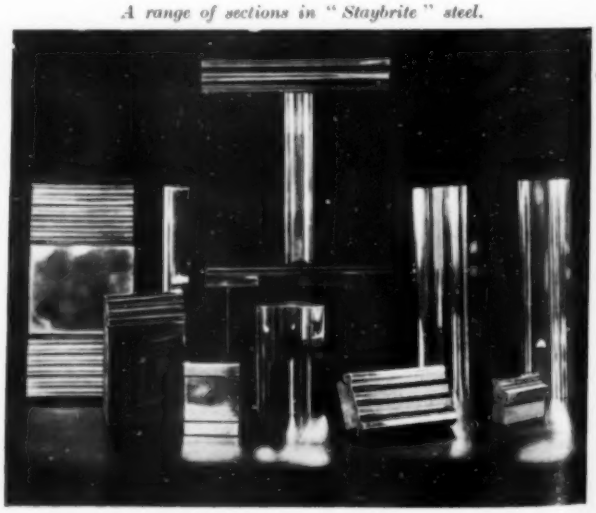
difficulty is experienced in fabricating work in these alloys, since they can be readily bent to shape, forged, drilled, and machined, and, if necessary, lacquered. They are available as sheet, strip, bar, rod or castings, and are obtainable in extruded form from the firms already mentioned.

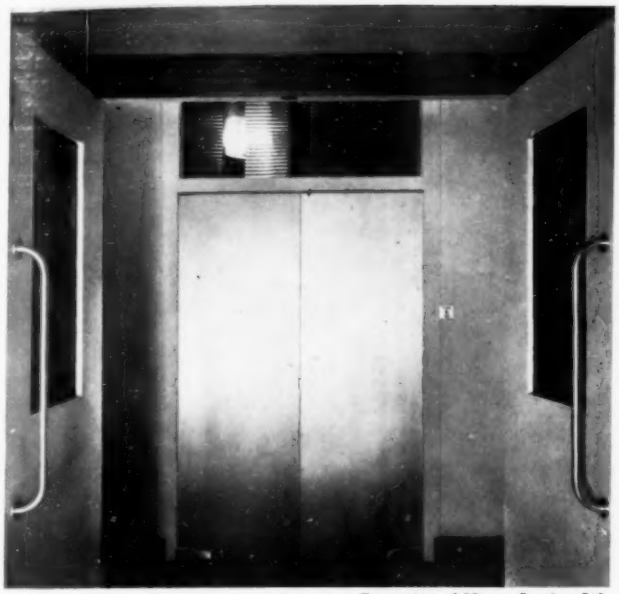
Aluminium Alloys.

The advantage of white metal finishes requiring little upkeep is generally recognised, but they are not attractive to everyone's sense of beauty. A wide variety of effects can, however, be obtained by using aluminium alloys, and during recent years their application for architectural purposes has made great progress. They are relatively cheap, and no expensive treatment for maintenance is necessary, providing a suitable type of alloy is chosen.

Several processes may be employed to supply the desired finishes, such as sand-blasting, scratch-brushing, and dipping in caustic soda and nitric acid to give a frosted finish, but the anodic process is more widely used at the present time. By this latter process the natural film of oxide on the surface of aluminium alloys is thickened and its protective effect improved. This coating of oxide is integral with the metal, and cannot be chipped or flaked off. The process may be varied to provide a very hard film, or a soft flexible film capable of being bent or formed. An important feature, from the decorator's point of view, is the fact that the oxide film can be treated to give a wide range of brilliant colour effects fast to light. A series of finishes is thus available to architects, in colours and tones which harmonise with any desired scheme. Not all alu-

A range of sections in "Staybrite" steel.





By courtesy of Messrs. Lumium Ltd.

New offices decorated with aluminium.

The pay-box of the Warley Cinema in Birmabright alloy.

minium alloys are equally suitable for anodic treatment, but a number have been developed which give consistent and excellent results when treated by this process.

Wrought and cast alloys have been specially developed for this class of work, and mention may be made of N.A.2 S, a commercially pure aluminium, and N.A.3 S, an aluminium manganese alloy, which are often used for sheet-metal work, the latter having a slightly higher strength. Another alloy recently developed is B.A.57 S; this is used where a harder surface is required or for stressed construction. These alloys are also available in a wide range of extruded sections up to about 8 in. wide, including additional alloys N.A.51 S and N.A.55 S. The latter are high-strength heat-treated alloys widely used for furniture, window-sections, and general moulding, and are usually supplied in the solution heat-treated temper in which reasonable strength and high ductility are available. These sheets and sections are supplied by the Northern Aluminium Co., Ltd. They give excellent results in natural or coloured finishes when anodically treated, and they are easy to fabricate.

Casting alloys are frequently necessary for decorative castings, such as grilles, etc., and the N.A.123 alloy is especially suitable for this purpose. It is a 5% silicon alloy possessing good casting qualities, and enabling large castings to be produced with intricate detail. This alloy has good corrosion-resistance qualities, but for higher strength and better corrosion resistance N.A.305 alloy has been developed.

Another noteworthy aluminium alloy for architectural purposes is Birmabright alloy. It is available in all constructional forms, cast and wrought, and is readily fabricated or welded. It has high mechanical properties, which are obtained without heat-treatment, and its corrosion resistance qualities are excellent. This alloy can be anodically oxidised readily in all forms for decorative or especially protective effects. It is being increasingly employed as an architectural metal for doors and window fittings, balustrades and grilles, metal furniture, panellings, etc. For interior decorative metal work its bright polish can be retained with little attention other than an occasional rubbing down with a soft cloth to remove deposited dirt. The aluminium alloy R.R.56, supplied by High Duty Alloys, Ltd., is also being applied for architectural purposes in the form of tubes.

The Gates of the Royal Academy, Burlington House. Designed in "Staybrite" Steel by Mr. Reco Capey, A.R.C.A., F.R.S.A.

Stainless Steel.

Probably the most recent of the architectural "white" metals is stainless steel, the development of which has facilitated engineering progress. The use of this steel for interior decoration, particularly the type known as "Staybrite," manufactured by Firth-Vickers Stainless Steels, Ltd., possesses four essential claims to consideration as a metal suitable for this purpose. Its workability and the way in which it lends itself to all the usual methods of manipulation; its strength; its resistance to climatic and other conditions of corrosion; and its brilliant finish when this is desirable. This steel may be completely softened by heating to a temperature of about 1,050° C. and cooling in air or water. Actually, it is supplied in the softened condition, and no further heat-treatment is necessary unless it has been severely cold-worked.

This steel is extremely ductile, and may be obtained in the form of moulding of almost any form drawn on to hard wood. It is supplied as sheet with either a mirror finish, dull satin finish, hammered finish, corrugated, crocodile skin, engine turned, or any of the other ornamental finishes. It may be cast into ornamental shapes which are unsuitable for fabrication by other methods, or it lends itself readily to the most beautiful repoussé work. In the construction of the ornamental gates at Burlington House, Mr. Reco Capey, the architect, also made use of bright bars of "Staybright" steel, hand hammered like wrought iron. The effect is very striking. Furthermore, if it is necessary to join two pieces rigidly together, or if the design demands that metal be built up to fill a small cavity, it may be welded, silver-soldered, or soft-soldered in the ordinary way.

In strength, this steel is equivalent to an ordinary steel, and possesses a tensile strength in the order of 40 tons per sq. in., while its corrosion resistance is well known. Unlike plated materials, the finish is indestructable, and even when scratched it does not look tarnished and untidy. All that is required to maintain a perfect finish is a rub over now and again simply to remove any dirt which may have accumulated.

In the space at our disposal it has only been possible to suggest briefly the potentialities of the metals mentioned. With the advance of metallurgical science the metals now obtainable are capable of adding dignity to the treatment of interiors. That this contribution of the metallurgists is opportune and welcomed may be concluded from the many new buildings in which these alloys are featured to advantage, so much so that they may be said to have contributed to a great extent to the spiritual appeal of modern architecture.

Soviet Kazakstan—An Important Centre of Non-ferrous Metallurgy

By A Special Correspondent

KAZAKSTAN is advancing to the first place among Soviet centres of non-ferrous metallurgy, and it is interesting to note how this has come about. The industrial development of this Republic began only after the October Revolution. Previously a backward and neglected province among Tsarist colonial possessions, Kazakstan received during the period of the first five-year plan 435 million roubles for industrial construction. Among the enterprises are the Karaganda coal mines, the chemical combine at Aktiubinsk, and a lead combine. At the end of the first five-year plan, the total value of industrial production was 250 million roubles, as against 69 million roubles in 1929. But greater investments were made in Kazakstan during the first two years of the second five-year plan than had been made for the whole of the preceding period, the total for industrial and railway construction in 1934 exceeding 500 million roubles.

How and why has Kazakstan attained this advanced position among Soviet centres of non-ferrous metallurgy? This Republic is estimated to possess, out of the total mineral resources of the Soviet Union, 78% of the lead, 64% of the copper, 72·5% of the nickel, 50% of the zinc, 30% of the oil, and more than 80% of the antimony, while Kazakstan occupies third place among the country's coal-producing regions.

Now what is being done to develop these resources? The giant copper-smelting combine, begun at Balkhash in 1933, will be ready for work next year, on completion of the railway from Karaganda. This combine will have an annual output of 100,000 tons of copper. Another huge copper combine is planned in the vicinity of Jezkazgan, where deposits of this metal in an area of 10 sq. kilometres are reckoned at about four million tons. The Ridder and Karsakpai copper mines are being reconstructed. New copper mines will soon be ready for operation at Belousov, while the lead mines and the lead plant at Chimkent are being pushed to produce at their full capacity.

Thus we see what is being done to develop the natural resources of Kazakstan, plans which so far do not include working the rich deposits of manganese, lead, zinc, and gold in the vicinity of Jezkazgan. Plans are under way for exploiting Kazakstan's extremely rich resources of antimony, nickel, borates, molybdenum, tungsten, and tin. The coal fields of Karaganda are another reason why Kazakstan has become such an important centre of non-ferrous metallurgy. Situated not far from Jezkazgan and Balkhash and in the very heart of Kazakstan, these fields are estimated to contain 55 million tons of coal. The advantage of their position, near the Ural metallurgical plants, cannot be overestimated, in view of the fact that these fields are rich in coal which can be converted into coke. Construction of the railway from Karaganda to Magnitogorsk and Orsk will help the development of these coal fields. Karaganda is now the third largest coal base in the Soviet Union. Within the next few years it will be the centre of a large-scale coke and chemical industry.

A great deal has already been written about the wealth of oil in the Emba district, so that this question will not be touched upon. It need only be said that this district, the Altai, with its apparently unlimited resources of raw minerals, rich hydro-power resources, mild climate and favourable conditions for agriculture, cannot be overlooked in relation to Kazakstan as a big centre of non-ferrous metallurgy. Reference must also be made to the natural resources in the vicinity of Aktiubinsk, in the Emba district. Near Aktiubinsk there are hugh deposits of superphosphate and precipitate—materials for fertilisers—and a large precipitate combine which has already been completed there, also the equally large deposits of sulphate along the Aral Sea, and the possibility of making this section of Kazakstan the centre of an important chemical industry.

Discovery of Mercury in the Altai Range.

Occurring chiefly in the sulphide ore called cinnabar, and seldom in its metallic state, deposits of mercury in the metallic state have been discovered in the Altai mountains in the Oiratian Autonomous Province of the U.S.S.R.

The discovery was made by the Lomonosov Institute of the Academy of Sciences. The Academy has been prospecting for mercury in various parts of the Soviet Union for several years, and this latest discovery is the second since 1931, when deposits were found near Chagan Uzun village in the same district.

In an interview with the correspondent of a Moscow newspaper, Mr. A. A. Saukov, a specialist at the Lomonosov Institute, described both the earlier and latest finds. The deposits this year were discovered by the geologists V. A. Kuznetsov and A. S. Mukhin. The deposits are characteristic in that they appear in combination with cinnabar, some of this ore containing no less than 5% mercury. The silver-white liquid metal in its pure state, however, is only a small proportion of the total deposits, according to Saukov, who shares the opinion of other scientists that the mercury belt of Oiratia is not confined to the vicinities of Chagan Uzun and Ak-Tash (where the second deposits were found).

Deposits of mercury at Chagan Uzun, Saukov said, run along the left bank of the Chui River, the bright red cinnabar ore containing it being found mostly in limestone. Cinnabar is encountered in this country, experts say, in mountains ranging from 1,000 metres to 3,000 metres above sea level. However, the distribution of cinnabar is uneven, and prospecting is now being carried on under the direction of the engineer A. N. Vukolov to determine the exact percentage of mercury in this ore.

Discovery of mercury in the Altai mountains, Saukov further said, is important for two reasons. In the first place, the other known source of the metal, Nikitov village in the Donetz Basin, is no longer capable of supplying the needs of the gold and electro-technical industries of the U.S.S.R. In the second place, the discovery will refute the theory that the Altai mountains are poor in minerals.

Recent Progress in Special Steels

By Sir ROBERT HADFIELD, Bt., F.R.S.

Membre Correspondant de l'Académie des Sciences.

At the recent International Congress on Mining, Metallurgy, and Applied Geology, held at the Sorbonne in Paris, some 360 papers were presented, which dealt exhaustively with the various subjects in their many aspects. Not the least important of these was the paper on the above subject, presented by Sir Robert Hadfield, who as delegate of the Iron and Steel Institute spoke at the opening session. In his paper, an abstract of which is given in this article, Sir Robert stressed the rapidity of the developments and the importance of alloy steels in modern engineering, and pointed out the great scope which still remains for future developments. He paid tribute to the great work accomplished by French metallurgists, and the important contributions they have made to the knowledge and applications of special steels.

The opening meeting of the Congress, at which Sir Robert Hadfield spoke as Delegate of the Iron and Steel Institute.

IN presenting this review of the progress made in recent years in the knowledge and use of special steels, the author paid tribute to the great work accomplished in this field by French metallurgists. To have given the names of all would have taken an undue proportion of space, but prominently to his mind, arranged in alphabetical order, come those of Brustlein, Breuil, H. Le Chatelier, A. Le Chatelier, Chevenard, Cheveneau, Charpy, Cornu-Thenard, Dumas, Euverte, Fayol, Fréminville, Frémy, Gautier, Guillaume, Girod, Gruner, Guillery, Guillet, Grenet, Harmet, Héroult, Holtzer, Jordan, Mesnager, Montgolfier, Pierre Martin, Osmond, Pourcel, Portevin, Perrin, Schneider, Saladin, Werth, and Maurice de Wendel. M. Charles Frémont, although an engineer by profession, greatly assisted ferrous metallurgy by his many important practical and useful researches. The author can vouch for this personally, having himself benefited so greatly from these valuable contributions by Frémont. These names and many others are known throughout the world of iron and steel, and if space permitted much could be told of their valuable contributions to ferrous metallurgy.

Rapid Progress of Alloy Steels.

The present review covers the period of the past ten years or so. Such has been the almost phenomenal progress in the field of alloy steels since the commencement of their effective use in industry, which many distinguished metallurgists associate with the introduction of manganese steel, invented by the writer some fifty years ago, that to cover any appreciably greater period would require much more space than is here available. On the other hand, any period less than ten years would be inadequate, since the development of a new alloy or process usually requires a decade or more—that is, before it can become fully established in industry.

In broad aspect, the progress to be recorded in this period may be described as a vigorous further expansion of the era of alloy steels which at its commencement had already become well established. (It concerns both the newer alloy steels, which this period has seen initiated, and also the developments which have taken place in the use of those important alloys which had already found practical application, such as manganese steel, silicon steel, nickel steel, chromium steel, tungsten and other alloy steels.)

In the period under review progress in engineering has continued in its main lines of development by increasingly intensive conditions of working—still higher speeds of locomotion, higher temperatures in furnace operation, and both higher temperature and higher pressure in steam practice and chemical engineering, also extraordinary development and use of electricity in so many forms, including those used in metallurgical practice.

The use of alloy steels, which is so essential for achieving these advances, has therefore continued to extend.

Special or alloy steels occupy a most important and prominent position in the world to-day. The growth has been very rapid during the past 10 to 15 years, and out of a production in the world of some 80 million tons of steel it may be said that about 8 to 10% of this tonnage is represented by alloy steels. Further, 1 ton of alloy steel takes the place of three to five times this tonnage of ordinary steel, and fulfils purposes for which ordinary steel could never be employed.

Heat- and Corrosion-Resisting Steels.

The distinguishing feature of this period has undoubtedly been the way in which the heat-resisting and corrosion-resisting ferrous alloys, mostly containing rather high proportions of chromium, or of both nickel and chromium, have been taken up and applied in industry. Trials in several practical directions had already clearly shown how valuable they might be. Their application on an ever-increasing scale has since demonstrated their great utility. It is noteworthy that in the peak year 1930 the annual production of these types of steel had in the United States already reached some 60,000 tons. Although the United States has in this and other fields shown itself specially receptive of new developments, this figure may nevertheless be taken as a useful index of the general progress made in the practical utilisation of heat- and corrosion-resisting steels.

Corrosion-resisting steels of a variety of compositions are now used for a wide range of applications, including

Group of forgings for the record-breaking car "Bluebird."

domestic and office fittings, furniture and utensils, apparatus and plant for the manufacture of chemicals, also for industries in which chemical processes are used; the manufacture and transport of foods, mechanical and civil engineering, and in the construction of scientific instruments and apparatus.

So far the greatest quantities have been demanded for domestic and decorative purposes, and in chemical industries. Engineering applications are, however, growing in extent as the benefits to be derived from corrosion-resisting steels become more appreciated, and as experience is gained by actual trial of their value in dealing with cases where corrosion and its effects are an important factor. Notable examples of such uses on an apparently large scale are for the reinforcements of the masonry in the restoration of St. Paul's Cathedral, London, for which purpose some hundreds of tons of special high tensile corrosion-resisting steels were used, also for the Sennar and Aswan Dams on the River Nile, for staunching bars and concrete reinforcements respectively. Over 1,000 tons of such steel are also reported to have been used during the past year in revetment work on the River Mississippi, mainly in the form of wire cable, solving the serious problem caused by breakages of the previous cables of ordinary steel.

The use of heat-resisting steels similarly grows apace. The earlier appreciation of the value of these steels was in connection with the valves of internal combustion engines; the rapid advances made in these, specially for aircraft and racing motor-cars, have placed a high and exacting duty on the valves. For this development the introduction of heat-resisting steels was particularly opportune. In engines of the most up-to-date type valves may reach a temperature as high as 900° C., and suitable heat-resisting steels are successfully able to survive this exacting service. Nowadays the use of heat-resisting steels has extended much beyond this particular application, and they are regularly utilised in boiler and furnace plants, and high-temperature equipment of all kinds. Ferrous alloys are now available which are non-scaling for practical purposes at temperatures up to 1,200° C. and even higher.

The chemical industry has also greatly benefited by the use of heat-resisting steels, since these provide suitable materials for the vessels necessary for modern high-temperature high-pressure processes, and which are at the same time resistant to the specially vigorous chemical activity occasioned by such high temperatures, and also are not subject to penetration of the gases, such as hydrogen.

Improvements in Ferro-Alloys.

In any reference to developments in alloy steels, acknowledgment should be made of the steady improvements in ferro-alloys and the introduction of new and useful combinations brought about by those firms engaged in their manufacture, to keep pace with the extending requirements of steel-makers. French metallurgy has indeed a well-earned reputation in this field, and the author mentioned Messrs. Eyverte, Gautier, and especially Pourcel, of the Terre Noire Company, who successfully overcame the difficulties of producing ferro-manganese of high percentage, without the use of which the invention of manganese steel by the author could not have resulted when it did.

At one time 80% ferro-manganese was actually sold at under £8 per ton, and even now at about only £10 per ton, whereas by the older methods of manufacture the cost was ten to fifteen times the amount per ton just mentioned. Moreover, M. Pourcel's researches enabled the modern production of steel of all grades to be satisfactorily and economically accomplished in a manner that was otherwise previously not possible. It is often not realised that if rich ferro-manganese was to disappear only steels of inferior grade could be produced. Its scarceness during the war clearly proved this to be the case.

Of more recent developments, special mention may be made of the production of ferro-chromium of very low carbon content, so necessary for the manufacture of non-corrodible steels of the nickel-chromium type.

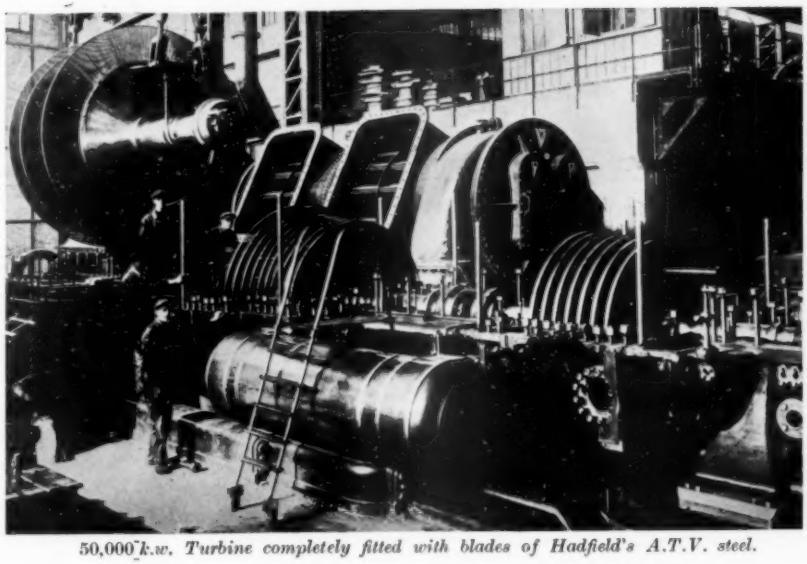
Development of Welding Methods.

The wonderful development of welding methods, both electrical and gaseous, in this period has also been of great advantage to the development specially of the corrosion-resisting steels. At their introduction successful methods for welding these steels of high chromium or nickel and chromium contents were non-existent, though their successful fabrication into many of the vessels and forms in which they were required for use necessitated welding. Such welds of a perfect character are now readily produced. The proceedings of the important symposium on the "Welding of Iron and Steel," held in London in May of this year by the Iron and Steel Institute, in conjunction with other technical societies, and comprising no less than 150 separate papers, form an excellent record of the progress so far made in technique and in the many directions in which welding is now so successfully employed.

Special Steel for Turbine Blading.

Particular mention should be made of the nickel-chromium steel specially developed for use in steam turbine blading, and known as "A.T.V." (Acier Turbines Vapeur). The use of this alloy in turbines prior to 1925 had been sufficiently long to establish its merits, and in the

period under review these merits have been recognised to an ever-increasing extent. Turbines of a total of some 8,000,000 h.p. are now bladed, some in part only, but many throughout, in "A.T.V." The accompanying illustration shows a 50,000 k.w. turbine completely fitted with blades from steel of this brand.



50,000 k.w. Turbine completely fitted with blades of Hadfield's A.T.V. steel.

Tool Steels.

In quite another direction a development which has also occurred almost wholly within the present period, is the introduction of new types of tool steel, the essential feature of which is the incorporation of cobalt in the rather large proportion of 15 to 20%. Besides giving a greatly increased performance in rate of machining, these new steels are able to accomplish tasks quite beyond the capability of the tungsten-chromium and tungsten-chromium-vanadium types. They have, in fact, thus provided a means for machining in a practical way manganese steel, which for all practical purposes had previously been regarded as non-machinable. These new tool steels are for some purposes rivalled by new non-metallic cutting materials of the tungsten-carbide type which have also been developed in recent years, and which for some purposes are unexcelled. For heavy cuts and handling rough surfaces these latter, however, cannot compete with the tool steels containing cobalt.

Magnet Steels.

In the field of permanent magnets, in view of the striking advance which had been made by Professor Honda with his steel containing cobalt, as compared with the previous tungsten steel regularly employed for this purpose, it was scarcely to be anticipated that a further improvement of any considerable magnitude was possible. Nevertheless, in the present period steels of several new types have been discovered as much exceeding in their performance that of the cobalt steel, as that in its turn was superior to tungsten steel, providing an excellent demonstration that the field of alloy steels is as fertile as ever in discoveries for those who will search for them.

Nitriding.

The title "Special Steels" would seem to permit reference also to a further development, which could not strictly be included under the term "Alloy Steels," and to which, in view of its importance, it would be a pity in any case not to refer—namely, the nitriding process. As a means of surface hardening of steel as an alternative to carburising (case-hardening) and without the many disadvantages and difficulties of the latter, this process, introduced by Dr. A. Fry, has found a definite field of utility. Providing as it does considerably higher hardnesses, and without the necessity of heating to specially high temperatures, with the consequent distortion and risk of cracking, it is proving highly useful. Its uses are concerned rather with those applications where the effects of abrasion or erosion are important but the mechanical forces at play not too vigorous. Recently the application of the process has been extended to several types of austenitic steel.

Manganese Steel.

For applications involving heavy abrasive action, such as crushing machinery, tramway points and crossings, and many others, it has still to be recorded that the steel known throughout the world as the Hadfield manganese steel, and still practically of the same composition and requiring the same treatment as when originally discovered and invented by the author, continues to hold its own.

Silicon Steel.

Silicon steel, meaning the steel containing high percentages of silicon up to about 4%, with low carbon, the use of which is also on an enormous scale, while remaining substantially the same steel as when first invented by the author, has since undergone considerable improvement in its properties. The magnetic characteristics of high permeability and low hysteresis loss to which it owes its applications are, it has been found, particularly sensitive to the presence of those elements such as sulphur and carbon, even in the small accidental amounts which are ordinarily present in steel. Development of metallurgical knowledge has also shown that these magnetic properties are further connected to a considerable extent with the size of the crystal grains. With attention to these features in the steel-making and heat-treatment processes, the magnetising losses of the material have decreased in a very marked way. Whereas when the steel was first introduced on a manufacturing basis, the guaranteed maximum loss was, in the usual units and at a frequency of 50 cycles, as much as 1·83 watts per kilogram. By improvements in composition and heat-treatment it is now being supplied under a guarantee of only a little over 1 watt per kilogram. The progress which has resulted in this improvement has gone on continuously, and much useful advance has been made during the past ten years.

As with manganese steel, so with silicon steel. No material has yet been discovered to take its place for those applications in power and lighting transformers, electrical generators and motors and other electrical purposes for which its properties are so eminently suited. Although in recent years there have been introduced nickel-iron alloys with 50 and 78% of nickel having somewhat similar characteristics and which have been applied in telephone and telegraph cables, magnetic instruments and wireless apparatus, these are of too expensive a character for the larger applications, and do not possess the characteristics essential for these to the same degree as silicon steel, specially its higher permeability at high magnetising forces.

High Tenacity Steels.

The number and variety of special steels now available for high tensile and structural purposes have greatly increased in recent years, and for many applications there is now an almost embarrassing choice available of steels, each excellent in its qualities of high tenacity combined with toughness. To such an extent is this the case that among high tensile steels selection is often a matter of personal predilection on the part of the engineer, for steels of a particular type. To the older chromium and nickel-chromium steels there are now added such combinations

as chromium-vanadium, chromium-molybdenum, nickel-chromium - molybdenum, nickel - molybdenum, and manganese-molybdenum, with varying proportions, usually not more than a few per cent. of these elements, though these do not exhaust the range.

For the construction of Sir Malcolm Campbell's record-breaking "Blue Bird" car it was thus possible to select for the various parts of the frame, transmission, and engine components those steels which incorporated just the right combination of properties for their individual requirements—that is, in the use of very carefully prepared alloy steels of the finest and highest qualities. Sir Malcolm's success must have been due in no small measure to this fact. A selection of the components constructed in special steels and supplied by the author's firm for his car is shown in an accompanying illustration.

One of the more recent and noteworthy arrivals is the steel with 3 to 7% of chromium, having a small addition of molybdenum and an excellent toughness even in the form of steel castings, that is not forged or rolled, besides also possessing certain claims to moderate heat- and corrosion-resisting properties.

Structural Steels.

The use of special high-tensile steels for large structures, such as bridges, is extending, and seems to have become essential also for the more important portions of the hull plating of modern high-speed liners. In the *Bremen* it is understood some 7,000 tons were incorporated, with a tensile strength of 33 to 38 tons per sq. in., and resulting in a saving of about 800 tons in displacement. Similar use was made in the *Europa*, and the *Normandie* is stated to include 5,000 tons of high-tensile steel in her hull.

The introduction of special steels into the field of those steels which are required in large tonnages has always been a matter of considerable difficulty. These and other indications, however, show that they could not be excluded indefinitely, and that it was worth while to overcome those manufacturing difficulties, whether in the provision of special control methods or of improved plant, and thus to acquire some of those advantages which special steels have so fully demonstrated in other and more restricted directions.

Scope for Further Research.

Although practically all the binary ferrous alloys of a likely nature have now been explored, there still remain among the ternary and higher systems great possibilities, as witness the discoveries of new and remarkable permanent magnet steels. Search of a systematic character necessarily becomes much more difficult as the number of added elements increases. In these circumstances increased resort must be taken to simple pioneering, aided by such clues as present themselves. It is indeed a remarkable fact that great as has been the increase in our metallurgical knowledge, there is still ample work in front of the metallurgist to obtain full and adequate scientific understanding and knowledge of the principles of the alloying of iron with other elements, to say nothing of a similar position as regards non-ferrous alloys, with which, of course, this paper does not deal.

It is appropriate to refer to the pioneer work of the great Faraday on alloy steels, because, although this was accomplished by him more than a century ago—namely, during the years 1819-1824—full information as to the alloys he made was only acquired, and their properties examined, some four years ago, that is at the time of the celebration in 1931 of the Centenary of Faraday's discovery of electro-magnetic induction; but the practical adoption of alloy steels was not then really necessary or wanted, and certainly not on a large scale. Nevertheless, the modern engineer and electrician could not have proceeded as far as he has done to-day but for the use of alloy steels.

Alumina Crucibles

Notable New Productions for Metal Testing

OF great interest in connection with very high temperature testing and research work in the field of metals is that alumina crucibles, boats, and similar pieces are now being manufactured by the Thermal Syndicate, Ltd., of Wallsend-on-Tyne, well known for fused silica-ware equipment.

Alumina laboratory ware for very high temperature work.

These alumina crucibles are in two grades of porosity, high and low, and at the present time can be manufactured in sizes up to 2½ in. external diameter and 3½ in. high. They will stand an extremely high working temperature of 3,540° F. (1,950° C.), and are very suitable therefore for the melting and general heat-treatment of all kinds of materials, not only metals and alloys, but also alkalis, acid materials, salts, and refractories, the rate of chemical reaction being extremely slow.

The main advantage of the alumina crucible in comparison with fused silica is the unusually high temperatures that may be used. It may be remembered that silica melts more or less completely at about 3,090°–3,272° F. (1,700°–1,800° C.) although volatilisation commences below this point, even as low as 2,460° F. (1,350° C.), while in general at about 2,678° F. (1,470° C.) a change-over from one crystalline form to another takes place with alteration of volume.

Silica ware of all kinds can, however, be used at temperatures up to, say, 1,830° F. (1,000° C.), and the method employed by the above firm in manufacturing their "Vitreosil" products consists, it may be remembered, in melting rock crystal or other forms of silica by electrical methods, passing a powerful current through graphite rods buried in the raw material. The result is to give three forms of fused silica, opaque, translucent, and transparent, according to the nature and properties of the original silica. The degree of transparency depends merely upon the amount of entangled gas particles, and the product is the same in each case, containing over 99·8% silica (SiO_2) which is then blown or melted into the desired shapes.

The valuable properties of silica ware, for many different applications, are due to the fact that the material possesses an extraordinarily low coefficient of expansion along with a high melting point. In addition, silica is strongly resistant to acids, transparent to the ultra-violet rays, and an excellent electrical insulator. During the past few years great advances have been made in the size and complexity of equipment made from silica ware, and some of the most notable industrial applications are tubes for the heat-treatment of metal objects of all kinds, pyrometer sheaths, windows for combustion chambers, and complete equipment for the manufacture and concentration of acids, such as nitric, sulphuric, hydrochloric, and acetic.

Correspondence

Copper Mixing and Smelting in Germany

The Editor, METALLURGIA.

Sir,—I read with very close attention the above article by Mr. Bertoya in your October issue, in order to compare the latest information with my own impression gained in an extensive tour of the Manofeld area in 1907, during my sojourn at Freiberg, in Saxony. I have compared the article with what I wrote and had published* at that time, and I find that my photographs taken then show quite a number of the features again named as specialities—*e.g.*, pouring the slag into brick forms and the dressing bench on which the old miners work at hand-picking.

I failed to notice what specially appealed to me: the telphers from the scattered mines to the krüg-hütte or coarse smelter, where they were still open-heap, calcinating the ore prior to smelting, which was done in three stages. They were then working the new Günther process of extracting copper from the slabs of cast matte, with recovery of the silver from the slimes. I specially noted the large use of electricity, and featured their electric winder, then a new feature of the Koepe sheave.

At that time the Bessemer plant was being tried as an experiment, and my photograph of the first converter had to be taken through a broken window, as the workmen were all at a triennial church parade, which was a general holiday, the works being then completely catered for in both food and entertainment by the controlling company, which even ran the field trams for passengers between their various villages on the ore field.

I remember seeing some very fine examples of fossilised fish taken from the copper shist, these having been completely converted into copper sulphide, with all the scale markings showing perfectly. I was much struck with the idea of a central pumping station in one of the old shafts, after the ore had been worked out in that area and the deeper shafts sunk farther to the east. What astounded me as much as anything was to see the wrapping paper from the lunch basket of one of the engine-drivers at the giant twin pumps. It was the Queen's birthday (May) music programme from the Royal Albert Hall, London, and the time was the end of July in the same year.—Yours, etc.,

J. S. G. PRIMROSE.

Acocks Green, Birmingham.
October 22, 1935.

Grain Size Control

The Editor, METALLURGIA.

Sir,—The austenite grain size of a steel of a given chemical composition and its control has become, lately, unanimously recognised as a most important factor in steel making. Being understood and rightly applied, it brings us a bit nearer to the "properly designed world" recently mentioned by Lord Rutherford. The fact that it is possible to produce from the same heat either inherently coarse-grained or inherently fine-grained steel, which, given the same heat-treatment, exhibit widely different mechanical and physical properties, must focus the attention of every steel-maker and user on the question of grain size and on the selection of the most suitable size for his specific purpose.

To-day there is no similarity in steels and their behaviour on heat-treatment, cold and hot working, even if their chemical composition be exactly the same, unless they belong to the same class with regard to inherent grain size. It is from information of this character that the body or personality of a steel is explained and is made a matter of knowledge rather than of speculation. There is another far-reaching effect resulting from the realisation of the value of grain size control. According to Shane, a good many special properties of steel, which were in the past associated with the presence of certain alloying elements, depend really, not on the alloying metals themselves, but on the influence which they exercise on the grain size and uniformity of the alloy. Thus plain carbon steel has once again gained a position where it can hold its own against certain low alloy steels.

Although the state of deoxidation of steel by means of ferro-manganese and ferro-silicon is of primary importance, the grain size is actually controlled by an aluminium addition by itself or in conjunction with other strong deoxidisers like titanium, vanadium, etc. This is best demonstrated by the works of Davenport and Bain, Epstein, Neadand, Washborn, and other investigators. Sufficient aluminium addition produces inherently fine-grained steel, whereas when no aluminium is added the steel produced is coarse-grained. According to Dr. Robertson, the influence of aluminium is due to the formation of its minute particles of alumina suspended in the molten steel, which act as nuclei in the formation of crystals.

It is plain therefore that in grain-size control the presence of oxygen in steel is as important as the presence of aluminium itself. Too much oxygen, however, tends to form large inclusions of alumina which are undesirable, even small quantities of oxygen are only good in steel in so far as they necessitate the use of aluminium to effect removal. The obvious question arises whether it is really necessary to use aluminium as a controlling agent for grain size and hold harmful oxygen in the molten steel in order that aluminium can be used. Would it not be possible to obtain the same effect by some other less dangerous means? I believe that steel can be deoxidised fully by means of silicon and manganese only, and if finely ground alumina is added to the molten metal in the ladle or mould and well stirred, it will do the same duty as is now expected from aluminium additions.—Yours, etc.,

B. SHEYNIN,
Professor of Technology.

Moscow,
October, 1935.

Electric Resistance Alloys

The Editor, METALLURGIA.

Sir,—I have read, with interest, the article on "Electric Resistance Alloys" which appears in your October, 1935, issue. I have been intimately connected with these alloys particularly of nickel-chromium (with and without iron), for the past 15 years. For the past four years, with my present firm of Hall and Pickles, Ltd., I have done a great deal of work in developing Kanthal, which is an alloy of the iron-chromium-aluminium type containing cobalt. I think, therefore, I may claim that I am speaking with authority when I say that certain statements in Mr. Peters' paper are definitely misleading.

Kanthal is being produced in wire equal in appearance and surface to any nickel-chromium wire. It is being drawn in my own firm's wire-mill in coils each of upward of 40 lb. of wire, and is being reduced to sizes well under 0·01 in. diameter. This wire can be made into heating elements, particularly for domestic appliance apparatus, with no more trouble than is required by nickel-chromium wire. When the life under temperature is compared, Kanthal alloys, even Kanthal D, which is the lowest grade, show themselves far superior to nickel-chromium alloys. Under the Bash and Harsch test, which has been standardised for testing electric resistance wires in America, Kanthal D shows an average of four times longer life than the best nickel-chromium alloys.

Contrary to what Mr. Peters states, elements made with Kanthal alloys do not lose their loading quicker than nickel-chromium alloys. My own experience is absolutely the reverse, Kanthal being much superior to nickel-chromium for maintaining the wattage. His claim that iron-aluminium-chromium alloys develop a large grain size after exposure to high temperatures is correct, but so do nickel-chromium alloys. Certainly the iron-aluminium-chromium alloys tend to become brittle when cold after being heated for a long period at high temperatures, but this brittleness depends on certain factors. Amongst them

* The Engineering and Mining Journal of New York, Oct. 12, 1907, pp. 671-4.

are the temperature and the size of the wire. For instance, a fine-gauge wire, say, of 23 or 24 S.W.G. (such as is used in the average domestic appliance), will remain quite ductile if heated only to the same temperature as the average nickel-chromium wire element—*i.e.*, under 1,000° C. Brittleness may be developed when this temperature is exceeded on a large gauge wire, but the brittleness need not be detrimental if care is taken in designing the element and its support.

Likewise with Mr. Peters' statement about sagging, design plays a very important part. Elements made with nickel-chromium wires will sag if the design of the refractory support is wrong. Given a little thought, it is easy to design a refractory former upon which Kanthal elements will not sag. In fact, with most of the best designs now employed for nickel-chromium wires, Kanthal is perfectly safe. For the new type of rod element (similar to the Ferranti) I claim that Kanthal wire is far superior to nickel-chromium wire.

I am afraid this letter would become far too long if I attempted to describe all the superior qualities of iron-aluminium-chromium over nickel-chromium alloys. Cleanliness of appearance, freedom from refractory alkali attack, cheaper cost per element, and numerous other advantages could be quoted. If Mr. Peters cares to get in touch with me, I shall be only too pleased to enlighten him on the value of these newer than nickel-chromium alloys. Like all new developments, Kanthal alloys have had their "teething" troubles. On occasions, set-backs have had to be faced, but gradually and surely these have been overcome. I am convinced that they have come to stay, and to greatly replace nickel-chromium alloys.—Yours, etc.,

Sheffield, October 22, 1935. J. H. RUSSELL, Works Manager. HALL AND PICKLES, LTD.,

The Functions of a Technical Information Bureau

A feature of modern industrial organisation is the development of research associations, the aims of which are in general to improve the products into which their materials enter and develop new uses for them. Progress is based essentially on fundamental research in the laboratory, and is greatly facilitated by a technical information service. The activities of such a bureau are described in Miscellaneous Publication No. 3 of the International Tin Research and Development Council, "The Functions of a Technical Information Bureau," by Dr. E. S. Hedges and Dr. C. E. Homer. The qualifications desirable in the personnel are research experience coupled with a practical outlook and capacity to appreciate the full significance and relative importance of information received from numerous sources. By studying the requirements of industry and the trend of research in other fields, the Bureau becomes not merely a storehouse of information but a valuable research instrument as well.

The collection and selection of information necessitates familiarity with every aspect of the work of the organisation. Sources utilised are technical and scientific periodicals, abstracts and papers, and patent literature. Trade literature, photographs, personal contacts, and correspondence are all of value for the same purpose.

Effective distribution of the specialised information to the appropriate research workers and to industry is achieved through several channels. Technical inquiries from industrial organisations, research associations, manufacturers and others from all over the world are answered in collaboration with the Director of Research with the co-ordinated assistance of various sections of the organisation. Since the widest distribution of information can be achieved through printed reports, monographs and bulletins, the publishing of them is undertaken by the Bureau.

Copies of the above publication may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Meters and Control Instruments at Transport Exhibition

An interesting display of temperature-measuring and control equipment is given by Electroflo Meters Co., Ltd., at the Public Works, Roads and Transport Congress and Exhibition, held in the Royal Agricultural Hall, London, on November 18-23. This display includes "long scale" multi-point indicators, and "long scale" automatic control pyrometers, all of which are also available as electrical distance thermometers. Additional temperature and pressure instruments comprise circular recording thermometers, indicating and recording pressure instruments, a combined temperature and pressure recorder, and a number of thermometer bulbs.

Probably the most noteworthy item is a "Flood-lit" canopy panel of patented design, carrying typical flush-mounted instruments, which are accompanied by a wide range of other equipment. Flow meters are represented by a working example of the Electroflo electrically operated venturi meter, a pedestal type meter body for open channel flow measurement, and a selection of orifice fittings.

Other interesting features include a completely self-contained recording level gauge for use with water, oil, or sewage contained in sumps, wells, or tanks. The Electroflo-Reineke regulator is shown as a working model operating a rheostat to control pump speed and maintain a constant pressure in the delivery main—a typical example of the many applications of this regulator. Additional exhibits are a motor-driven CO_2 recorder with indicating scale and pointer, edgewise scale flow and level indicators, and a number of smaller items.

Some Recent Contracts

Yugo-Slav Order for Yarrow's

A contract has been placed with Yarrow and Co., Ltd., of Glasgow, by the Yugo-Slav Government for boilers and machinery for three destroyers. On the signature of this contract the two Adriatic shipyards—that of Yarrow and Co. at Kraljevitza, and that of the Chantiers de la Loire at Split,—become amalgamated. The combined firm will build the hulls for the three destroyers, and also several tankers, barges, and harbour craft. The total value of orders to be placed with the two firms is £1,200,000.

L.N.E.R. Contracts

The L.N.E.R. report that the undermentioned contracts have been placed: Cranes (Dereham), Ltd., Dereham, three 3 ton trailers with platform bodies, eighteen 5-ton trailers with platform bodies, four 5-ton trailers with H.D.S. bodies, two 6-ton trailers with platform bodies, one 10-ton trailer with platform body, twenty-eight 3-ton loading platform trailers, forty 3-ton low loading fixed-sided trailers, fourteen 6-ton Standard loading level platform trailers, and eight 6-ton Standard loading level fixed-sided trailers; Scammell Lorries Ltd., London, W.C.1, nineteen M.H.3 mechanical horse tractors, eleven M.H.6 mechanical horse tractors, ninety-six sets 3-ton trailer coupling gear, four Standard 6-ton cranked frame trailers, two Standard 6 ton cranked frame trailers with flat platform bodies, and twenty-two sets 6-ton trailer coupling gear; and R. A. Dyson and Co., Ltd., Liverpool, twenty-eight low loading fixed-sided trailers and fitting of coupling gear.

The Admiralty announce that, subject to the settlement of certain points of detail, they have entrusted the construction of the machinery for a Southampton class cruiser of the 1935 programme to Scott's Shipbuilding and Engineering Co., Ltd., Greenock. The hull is to be built at Devonport. The machinery contract for the cruiser is estimated to be worth about £500,000. These ships cost about £1,750,000.

Contracts for the construction of two further cruisers of this class have been provisionally placed with the following firms:—R. and W. Hawthorn Leslie and Co., Ltd., Hebburn-on-Tyne, and the Fairfield Shipbuilding Co., Ltd., Govan, Glasgow. They will displace 9,000 tons each, with a main armament of twelve 6-in. guns.

Messrs. Cammell Laird and Co., Ltd., Birkenhead, have received an order for the construction of new machinery for the battleship *Renown*. This order follows the recent order for the aircraft carrier *Arkroyal* and the contract for a new Blue Star Line motor-ship of 12,000 tons.

The Strength of Metals under Combined Alternating Stresses

A research into the resistance of metals under combined alternating plane flexural and torsional stresses is described in a paper by Dr. H. J. Gough, and Mr. H. V. Pollard, recently presented to the London Section of The Institution of Mechanical Engineers. A specially designed high-speed fatigue testing machine was used. Three materials were studied and the results of the combined stress fatigue tests obtained indicate that this method of testing materials should prove useful in the design of engineering components. An abstract of the report is given in this article.

IN view of the profound importance of the subject to engineering design, the very considerable amount of theoretical and experimental attention which has been given to the study of the stress criteria which govern the failure of constructional metals under combined stresses is easily understood. Dealing with the subject in its broadest aspects, failure may be considered to occur (1) at breakdown of the condition of primitive elasticity, or (2) at the occurrence of further deformation during the yielding or plastic stage, or (3) at fracture; which of these events is of major importance in any particular case will depend on whether the requirements are such as to prohibit altogether plastic deformation or, alternatively, if while avoiding fracture they will yet allow a limited or unlimited amount of permanent set to occur. Each of these requirements is commonly encountered in examples of engineering practice. Again, the operative stress systems to be considered can, in general, be divided into those of a static or of a cyclic nature, or of a combination of these two. As the present paper deals essentially with the resistance of metals to combined cyclical stresses, it is unnecessary here to refer to the voluminous literature relating to the numerous theoretical and experimental studies of the behaviour of metals under combined static stresses, but it is mentioned that only in a few cases have the experimental conditions investigated been of sufficient variety and type to be discriminative.

A study of the very extensive literature relating to the behaviour of metals under cyclical stressing of "fatigue" reveals that, although considerable attention has been devoted to fatigue tests employing simple stress systems, such as direct, flexural, or torsional stresses, practically no information exists concerning the effect of combined fatigue stresses. This absence of information does not arise from any lack of theoretical or practical importance attaching to this aspect of fatigue phenomena—the majority of engineering problems of fatigue are concerned much more with complex stress distributions than with the simpler cases which have already received such intensive study but is probably partly due, in the first place, to the normal development of methods of attack on the fatigue problem and perhaps in no small measure to the fact that the design of a satisfactory high-speed combined-stress fatigue testing machine presents considerable difficulties; the present research represents the first really comprehensive attack on this interesting aspect of the strength of metals.

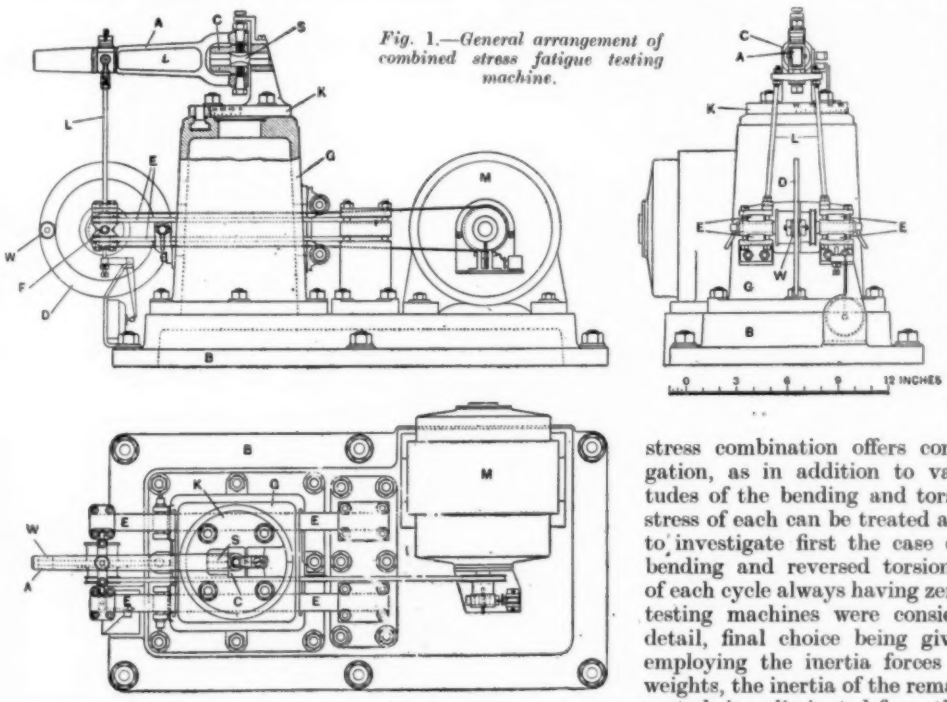


Fig. 1.—General arrangement of combined stress fatigue testing machine.

In planning the present research, it was decided that an investigation into combined fatigue stresses might usefully be commenced using stress combinations of two systems of cyclic stresses of different types, in phase; because combined bending and torsional stresses are commonly encountered in engineering—*e.g.*, in crankshafts, a commencement has been made with this combination. Even this simple stress combination offers considerable scope for investigation, as in addition to variations in relative amplitudes of the bending and torsional stress cycle, the mean stress of each can be treated as a variable. It was decided to investigate first the case of combinations of reversed bending and reversed torsional stresses, the mean stress of each cycle always having zero value. Several types of testing machines were considered and worked out in detail, final choice being given to a type of machine employing the inertia forces of revolving out-of-balance weights, the inertia of the remaining vibrating and rotating parts being eliminated from the specimen by a suspensory spring system whose natural frequency was in tune with that of the working speed of the machine. A machine for this purpose was constructed.

Combined-Stress Fatigue Testing Machine.

The general arrangement of this testing machine is shown in Fig. 1. One end of the specimen S is rigidly clamped in a movable bracket K bolted to the casting G which is attached to the baseplate B. The other end of the specimen is held in the collar C to which the arm A is pivoted about a vertical axis passing through the centre of the specimen. The disc D carrying the out-of-balance weights W is supported upon an axle F suitably clamped to the ends of the springs E, the other ends of which are rigidly clamped to a bracket carried by the baseplate.

The disc D is driven by the synchronous motor M, running at 1,500 r.p.m., through a belt drive. The bracket F is connected by links L to the centre of percussion of the arm A; a rubber bush is inserted between the ends of the links L and the arm A, so that the deformation of the specimen shall not be seriously constrained. Thus the general principle of the machine is that the out-of-balance forces, developed at the axle of the disc, are transmitted as an alternating moment to the specimen through the arm A.

The speed of the disc is adjusted—by varying the ratio of the pulley diameters—to the resonant frequency of all the moving parts vibrating on the outer ends of the springs E this adjustment is effected by the use of a very flexible specimen in the form of a thin strip. This is an important feature of the machine, as all inertia forces, other than those due to the out-of-balance weights, are thereby eliminated. The resonant speed of the machine shown is 2,130 r.p.m.

In the position shown in Fig. 1, cycles of reversed plane bending are imposed on the specimen. The bracket K and collar C can be rotated and clamped to any other position, so that the arm A makes an angle θ with the longitudinal axis of the specimen; the bending moment applied to the specimen is then proportional to cos θ and the torque to sin θ; it will be noted that the bending moment and torque are in phase so that they reach their maximum and minimum values simultaneously. Thus, when θ is 0°, cycles of reversed plane bending are applied, and, when θ is 90°, cycles of reversed torsion are applied, while any desired combination of bending and torsion is available by an appropriate choice of the value of θ. The machine is readily adjusted to apply alternating cycles intermediate between those of plane bending and pure torsion.

Test Programme.

Careful attention has been given to the most suitable range of materials to be used in this investigation. Although, in deciding on a research into combined flexural and torsional stresses, the problem of the crankshaft was primarily in view, it was not considered desirable to carry out tests merely on *ad hoc* ranges of commercial aircraft and automobile crankshaft steels, as the available combinations of chemical analysis and heat treatment thus offered are not very great; also the purpose of the work is not merely to collect test data but to obtain more fundamental information concerning the general criteria which govern the failure of metals under combined stresses. Accordingly, the programme embraces a wide variety of steels, some fourteen in number, which have been specially prepared to represent specific types of microstructure and regular variations in tensile strength; materials have also been included to give information on such aspects as the effect of a combination of a hard surface with a softer core, also of steels possessing similar static but widely differing impact properties, etc. To afford an opportunity of comparing the relative behaviour of "ductile" and "brittle" materials, also in view of the engineering interest attaching

TABLE I.—CHEMICAL ANALYSIS, HEAT-TREATMENT, ETC., OF MATERIALS.

N.P.L. Reference Mark.	Description.	Heat-treatment.	Chemical Composition, %.								
			C.	Si.	Mn.	S.	P.	Al.	Ni.	Cr.	Cu.
HEP	0·1% carbon steel	Normalised from 900° C.	0·12	0·185	0·61	0·012	0·016	—	0·06	trace	0·075
HGU	3½% nickel-chromium steel	Oil-hardened from 830° C. Tempered at 620° C. and cooled in water	0·31	0·21	0·58	0·002	0·017	—	3·65	0·85	—
HHV	"Silal" cast iron	—	2·09 (1·99 G.) (0·10 C.)	6·39	1·13	0·031	0·047	0·08	—	—	—

G., graphite carbon. C., combined carbon.

TABLE II.—SUMMARY OF RESULTS OF SUPPLEMENTARY STATIC, IMPACT, AND FATIGUE TESTS.

	0·1% Carbon Steel.	3½% Nickel-Chromium Steel.	"Silal" Cast Iron.
Tensile limit of proportionality, tons per sq. in.	11·2	18·2	1·8
Yield point in tension, tons per sq. in.	16·6	49·2	None
Ultimate tensile strength, tons per sq. in.	27·5	58·0	14·9
Reduction of area at fracture, %	70	65	0
Young's modulus E, lb. per sq. in. × 10^{-6}	28·7$_5$	29·0	17·4$_5$
Brinell hardness No. (0·4 in. specimens, using 5 mm. ball)	121	263	305*
Torsional limit of proportionality, tons per sq. in.	8·5	23·6	4·4
Yield point in torsion, tons per sq. in.	11·7	37·7	None
Torsional modulus of rupture, tons per sq. in.	32·7	52·3	23·8
Total twist at fracture ($L/d = 8\frac{1}{2}$)°	2,860	1,230	8
Modulus of rigidity G, lb. per sq. in. × 10^{-6}	11·4$_5$	11·4	7·6
Izod notched bar value, ft.-lb.	89·6	75·5	0·4$_5$
Fatigue limit (rotating bar), tons per sq. in.	±17·0	±33·7	±14·9
Endurance ratio	0·62	0·58	1·00
Torsional fatigue limit, tons per sq. in.	± 9·65	±22·6	±12·9
Endurance ratio	0·35	0·39	0·87

* On specimen 0·5 in. in thickness.

TABLE III.—SUMMARY OF COMBINED STRESS FATIGUE EXPERIMENTS.

Material.	Value of θ, °.	Ratio of Applied Twisting Moment to Bending Moment (tan θ).	Fatigue Limits, Tons per Sq. In.						
			Range of Direct Stress Due to Bending f, Tons per Sq. In.	Range of Shear Stress Due to Torsion q, Tons per Sq. In.	Ranges of Principal Stresses.			Range of Maximum Shear Stress S.	
					p_1 (tension).		p_2 (compression).		
					Value.	Ratio.		Value.	Ratio S/S_0
0·1% carbon steel	0	0	±17·4	0	±17·4	1·00	0	± 8·7	1·00
	15	0·268	±17·0	± 2·3	±17·3	$0·99_5$	± 0·3	± 8·8	1·01
	30	0·577	$±15·7_5$	$± 4·5_5$	±17·0	0·98	± 1·2	± 9·1	$1·04_5$
	45	1·000	$±13·3_5$	± 6·7	±16·1	$0·92_5$	± 2·8	$± 9·4_5$	$1·08_5$
	60	1·732	$± 9·5_5$	$± 8·2_5$	±14·3	0·82	± 4·8	$± 9·5_5$	1·10
	75	3·732	± 5·1	$± 9·5_5$	±12·5	0·72	± 7·3	± 9·9	1·14
	90	∞	0	$± 9·8_5$	$± 9·8_5$	$0·56_5$	$± 9·8_5$	$± 9·8_5$	1·13
3½% nickel-chromium steel	0	0	±35·0	0	±35·0	1·00	0	±17·5	1·00
	15	0·268	$±34·9_5$	$± 4·6_5$	±35·6	1·02	± 0·6	±18·1	$1·03_5$
	30	0·577	$±31·8_5$	± 9·2	±34·3	0·98	± 2·5	±18·4	1·05
	45	1·000	±26·6	±13·3	±32·1	0·92	± 5·5	±18·8	$1·07_5$
	60	1·732	±21·3	$±18·4_5$	±31·9	0·91	±10·7	±21·3	$1·21_5$
	75	3·732	±11·6	±21·6	±28·2	0·81	±16·6	±22·4	1·28
	90	∞	0	±22·8	±22·8	0·65	±22·8	±22·8	$1·30_5$
"Silal" cast iron	0	0	±15·6 (14·8)	0	±15·6 (14·8)	1·00	0	± 7·8 (7·4)	1·00 (1·00)
	15	0·268	$±15·2_5$	$± 2·0_5$	±15·5	$0·99_5$	± 0·3	± 7·9	$1·01_5$(1·07)
	30	0·577	±13·6	$± 3·9_5$	±14·6	$0·93_5$	± 1·1	$± 7·8_5$	$1·00_5$(1·06)
	45	1·000	±12·6	± 6·3	±15·2	$0·97_5$	± 2·6	± 8·9	1·14 ($1·20_5$)
	60	1·732	± 9·9	± 8·6	±14·9	$0·95_5$	± 4·9	± 9·9	1·27 (1·34)
	75	3·732	± 5·8	±10·8	±14·1	$0·90_5$	± 8·3	±11·2	$1·43_5$($1·51_5$)
	90	∞	0	±14·2 (13·5)	±14·2 (13·5)	0·91	±14·2	±14·2 (13·5)	1·82 (1·92) ($1·82_5$)

to the fatigue properties of cast irons, three types of cast iron have been included in the programme: these cover both the comparatively brittle and the comparatively ductile types, together with a high-quality engineering iron, which, in respect of ductility, is intermediate between the former two.

The resistance to combined fatigue stresses of each material will be investigated, using seven different combinations of bending and torsional stresses and, as lengthy endurance testing is the only reliable method of determining accurately the limiting range of stress, some considerable time must elapse before the results of the complete investigation are available. The present report deals with the results obtained from three materials: a mild steel, a heat-treated alloy steel and a cast iron specially chosen to represent an approach to a brittle material. Particulars of the three materials used are given in Table I. Supplementary static, impact, and fatigue tests are given in Table II, which show that the two steels are very ductile and possess good fatigue-resisting properties, while the cast iron is of uniform quality, is a very near approach to a brittle material, and possesses exceptional fatigue characteristics of considerable interest.

Results of the Combined Stress Fatigue Tests.

The results of the combined stress fatigue tests obtained with the ductile steels can be expressed by a simple relation $f^2/f_1^2+q^2/q_1^2=1$, where f and q refer, respectively, to the applied bending and torsional stresses at the fatigue limit of the combination, while f_1 and q_1 denote respectively the fatigue limits under simple bending and pure shear. The deduced fatigue limits are summarised in Table III, where these values are stated in terms of the calculated values of the direct and shear stresses due to the applied bending and twisting moments, respectively, also of the principal stresses, and the maximum shearing stress. Each result represents the range of stress which is just insufficient to cause fracture of the metal under an indefinitely great number of applications of the particular stress cycle employed.

The results of the combined stress fatigue experiments have been plotted in Figs. 2, 3 and 4, in terms of S/S_0 (Table III), to which, for purposes of comparison, the graphs of equations representing maximum shear stress, shear energy, total energy, principal strain and principal stress. The behaviour of the 0·1% carbon steel, Fig. 2, is seen to be in almost exact agreement with the von Mises-Hencky constant shear energy theory. But this cannot be regarded as a general criterion for steels, for Fig. 3 shows that the results—which are somewhat less regular—of tests on the 3½% nickel-chromium steel

Results plotted in form of polar diagram in terms of ratio S/S_0, where S = fatigue limit in terms of maximum shear stress.
S_0 = fatigue limit for special case of simple plane bending.
● denotes experimental values.

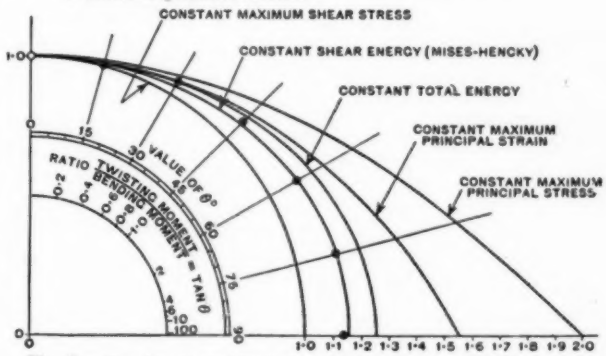


Fig. 2.—Results of combined stress fatigue tests on 0·1% carbon steel.

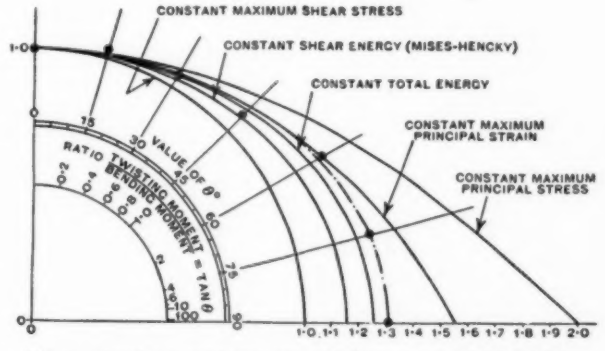


Fig. 3.—Results of combined stress fatigue tests on 3½% nickel-chromium steel.

are in close agreement with the curve of constant total energy. At the present stage of the research, in view of the considerable number of steels of various compositions and heat treatments yet to be investigated, the authors consider it undesirable to devote much discussion to the interpretation of these differences in characteristic behaviour under combined fatigue stresses.

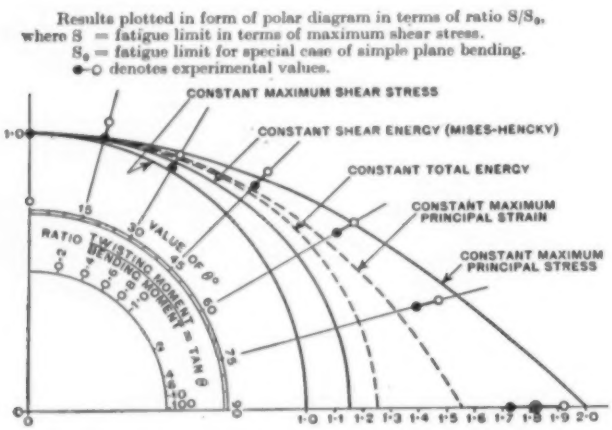


Fig. 4.—Results of combined stress fatigue tests on "Silal" cast iron.

Inspection of Fig. 4 reveals that "Silal" cast iron conforms reasonably closely to the criterion of failure by principal stress. Cast iron is regarded as being unusually subject to variations of strength from sample to sample, and for this reason one would not expect to obtain experimental data of such consistency as to afford conclusive evidence of the criterion of failure, unless an enormous number of specimens were used and a conclusion based on statistical methods was then derived. In this investigation a total of seventy-eight specimens of "Silal" have been subjected to mechanical tests and every fracture has been consistent with failure by principal stress.

The fractures of the specimens of the ductile steels afford no data regarding the plane on which failure first occurs; it may be that the path of the development of the crack—probably influenced by normal stress—bears in general little, if any, relation to the plane of initiation of fracture; alternatively, the plane of fracture may be determined by a combination of shearing stress and normal stress; or, again, both factors may be in operation, rendering the results impossible of interpretation.

Chromium now Successfully Recovered in North-west Ontario

The Chromium Mining and Smelting Corporation, Ltd., is now developing a chromium deposit at Obonga Lake, near Collins, Ontario. At the present time the company is drawing its raw ore supply from the stock pile at Collins, but underground mining is expected to start in November or December. Smelting and refining are being carried on at Sault Ste. Marie, Ontario, where two electric furnaces are now engaged and a third is being assembled. Dependent upon the type of alloy processed, from 60 to 200 tons of chromium alloys are being produced monthly. The following chromium products have been made from the North-Western Ontario ore: Beneficiated ore from 30 to 50% Cr_2O_3, 2–4% iron; Obonga metal, 10 to 50% chromium; high carbon ferrochrome, 50 to 80% chromium; chromic acid; carbon-free chromium alloy. The quantity of ore available is expected by the company to yield eventually about 40,000,000 lb. of recoverable chromium from ore ranging from 5 to 40% per ton.

Reviews of Current Literature

Journal of the Institute of Metals

The latest volume of the *Journal of the Institute of Metals*, (vol. LVI., No. 1, 1935) constitutes a complete record of the two most recent meetings of the scientific society that is responsible for the publication of this useful book. The respective gatherings were the Spring Meeting and the May Meeting, both held in London. At the latter, Professor W. L. Bragg, F.R.S., delivered the twenty-fifth annual May lecture, his subject being "Atomic Arrangement in Metals and Alloys." This discourse—in which an account of the theory of atomic arrangement in the crystalline structure of an alloy is given—is reproduced in full, and constitutes a valuable addition to scientific knowledge. It brings up to date the work that has been done on this subject since Professor Bragg's father, Sir William Bragg, F.R.S., delivered a previous May lecture—in 1916—on "X-rays and Crystalline Structure, with Special Reference to Certain Metals."

A dozen papers dealing with many aspects of metallurgical work make up the bulk of the present volume, these papers having been presented at the March meeting of the Institute of Metals. Two specially interesting groups are those dealing with fatigue in metals, due either to atmospheric action or to corrosion. Another group is devoted to the constitution or properties of tin alloys. "Unsoundness in Aluminium Sand Castings" and "The Mechanical Properties of Some Wrought Magnesium Alloys," are the titles of two other papers of considerable industrial importance. All these and other papers, which are very fully illustrated—for the most part by photomicrographs—are reproduced *in extenso*, together with a record of the discussions which took place when they were presented and written communications upon them that have been subsequently made.

As the March meeting was also the annual general meeting it is appropriate that in the present volume there should appear the report of Council on the work of the Institute for the past year, the report showing that the work of the Institute has been fully maintained.

"Journal of the Institute of Metals." Vol. LVI (Proceedings), No. 1, 1935. Pp. 306. 31 plates. Edited by G. SHAW SCOTT, M.Sc., F.C.I.S. London: The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. Cloth. £1 11s. 6d.

Metallurgical Abstracts (General and Non-ferrous)

"Metallurgical Abstracts," published under this title since January, 1931, and issued as a supplement to the monthly *Journal of the Institute of Metals*, has appeared hitherto as part of the Journal series. The present issue is the first volume of a new series; it appears in a distinctive binding, and is complete with its own index containing many thousands of entries. The extent of the publication can be gauged from the fact that the abstracts are gleaned from over one thousand of the world's scientific and technical publications by a staff of fifty-eight abstractors and reviewers whose names form an impressive list on the opening page of the new volume.

The subjects dealt with are grouped under twenty-four main headings, and range from "Properties of Metals" to "Industrial Uses and Applications." It is difficult to overrate the value of these abstracts to the busy man who desires to keep in close and regular touch with important technical developments in various parts of the world.

"Metallurgical Abstracts (General and Non-ferrous)." Vol. I. (New Series), 1934. Pp. 780. Edited by G. SHAW SCOTT, M.Sc., F.C.I.S. London: The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. Cloth. (Subscription price £4, inclusive of two "Proceedings" volumes).

Treatment of Precious Metal Matte

By C. C. DOWNIE

Base metals have an ever-increasing application to industry, but it should not be overlooked that precious metals have been responsible, in no small measure, for the discovery and colonisation of continents; it is, therefore, of interest to consider some aspects of their extraction from suitable ores.

PRECIOUS metal matte comes from two main sources —namely, reverberatory smelting and blast-furnace smelting. Rich gold and silver concentrates, sweeps, and residues, and practically all other rich auriferous materials are worked on the reverberatory furnace. The process consists of melting these on an almost flat-shaped hearth, to which has previously been added lead or arsenical lead, and some poor matte. The products are rich lead which goes to the "test" or cupellation furnace, matte which is roasted and treated by wet methods, and slag which is transferred to the blast-furnace. Poorer sweeps and residues (such as Rand sweeps from old melting-pots, etc.), which amount to about £200 in value, are briquetted and smelted on the blast-furnace. The products are the same as those from the reverberatory furnace, but poorer in quality, and the slag is thrown out as waste. For example the charges worked on the reverberatory furnace may only amount to from ten to fourteen tons per week, but may represent many thousands of pounds in value. The blast-furnace capacity is vastly larger, and besides working twice this quantity in weight, can also recover the precious constituents from slags, old brickwork, furnace bottoms, etc.

About one ton of rich matte is obtained weekly from the reverberatory furnaces, and approximately seven tons from the blast-furnace. The base-metal constituents in the matte, as with most other mattes, vary considerably, but on an average contain about 30% copper, and 10% lead.

The respective precious metal constituents of the reverberatory and blast-furnace mattes are as follows: (Given in ounces per ton.)

Reverberatory matte: 1,800 oz. silver, 15 oz. gold, 4 to 5 oz. platinum, and about 1 oz. of palladium.

Blast-furnace matte: 950 oz. silver, 6 oz. gold, and about 0·2 oz. of platinum.

The reason for the absence of iridium, etc., in the latter matte is that a certain amount of white-metal, or speiss-matte retains them, and is removed in the form of pot bottoms, or the skins which are left on the tapping pots, due to their higher melting point. The iridium, etc., is retained by the arsenical constituent of the lead in both furnaces, according to the process worked out by D'Hennin some fifty years ago. The treatment of the mattes consists of recovering the precious metal constituents as expeditiously as possible, but smelting methods are at a discount because of the high copper content. One smelting method consists of converting the matte to crude copper and electrolysing, but where a sale can be obtained for copper sulphate, it is more economical to adopt the wet process.

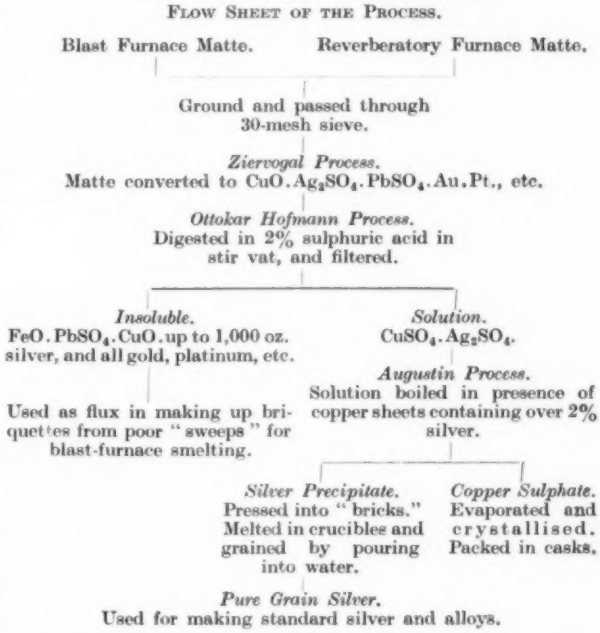
The mattes are, therefore, broken to small lumps in a breaking machine, and ground to fine powder in a ball mill, or a large pan mill. It is best practice to pass all matte through a 30-mesh sieve, but rougher material can also be successfully roasted. The soft nature of most precious metal mattes may be gathered from the fact that some 10 cwt. or more can be passed through the ball mill per hour.

The process from this stage may astonish metallurgists because of its antiquity, but it is the process in use at the present day, and was made great use of at the recent "gold rush." The old methods have been somewhat brought up to date so far as mechanical handling is concerned, but are operated on the ancient principles.

Wet Treatment

The ground matte is roasted according to the Ziervogal method at about 700° C., whereby silver is converted to the soluble sulphate, copper is oxidised to cupric oxide, and lead to lead sulphate. In short detail, the matte is first roasted, then dissolved in dilute sulphuric acid, as originally worked out by Ottokar Hofmann, and the solution finally exposed to the action of copper sheets whereby the silver is precipitated as a pure sludge, making use of the Augustin process. The roasting is performed on a Harris or similar type of roasting furnace, and the temperature must be under accurate control, since the formation of cuprous oxide is undesirable. The arms which hold the rakes for stirring up the mass, are either water-cooled, or are made of special heat-resisting steels. Mattes containing much lead tend to adhere to the roasting-furnace bed, but so long as this constituent is converted to the sulphate condition, it can do little harm.

TREATMENT OF PRECIOUS METAL MATTE.
FLOW SHEET OF THE PROCESS.


Blast Furnace Matte.
Reverberatory Furnace Matte.
Ground and passed through 30-mesh sieve.
Ziervogal Process.
Matte converted to CuO.Ag2SO4.PbSO4.Au.Pt., etc.
Ottokar Hofmann Process.
Digested in 2% sulphuric acid in stir vat, and filtered.
Insoluble.
FeO.PbSO4.CuO.up to 1,000 oz. silver, and all gold, platinum, etc.
Used as flux in making up briquettes from poor "sweeps" for blast-furnace smelting.
Solution.
CuSO4.Ag2SO4.
Augustin Process.
Solution boiled in presence of copper sheets containing over 2% silver.
Silver Precipitate.
Pressed into "bricks." Melted in crucibles and grained by pouring into water.
Copper Sulphate.
Evaporated and crystallised. Packed in casks.
Pure Grain Silver.
Used for making standard silver and alloys.

The beds of the furnace are connected to temperature controls, or a recording pyrometer arrangement, and the draught created by the flues is periodically checked. Another recording arrangement is also used to keep a record of the resistance offered by the matte, as when the latter is too sticky and adhesive, it adheres to the rakes, and curtails the operations. The roasting, on the whole is slow and tedious, and although worked continuously night and day, only roasts about 7 to 8 tons of matte per week.

The result of the roasting is that all gold, platinum, iridium, etc., remain in insoluble condition, as also does the iron which is converted to iron oxide, whilst the only soluble constituents are silver and copper. Should any nickel be present, it would also be soluble, and the process does not suit this class of matte.

Small quantities of nickel are retained by the speiss-matte, and in this way are more or less eliminated. Much nickel would give a solution containing nickel sulphate which crystallises at almost the same point as copper. The work is thus limited, and care is taken that rich nickel materials containing precious metals are avoided in securing the raw materials for the process. Details of the roasting were given by Ottokar Hofmann, and need not be repeated here.

The roasted matte is charged into a lead-lined vat, in small quantities at a time, some 10 cwt. being worked per eight-hour shift, although a much larger plant can be used if the tonnages should justify this. The vat is cylindrical in shape, and stirred by a propeller operated mechanically and is heated by steam heat from lead coils, as detailed by Hofmann.

The solvent consists of a 2% sulphuric acid solution, which content is maintained by frequent additions of concentrated sulphuric acid. That is, the roasted matte is allowed to flow into the vat in a continuous stream, which consumes the free acid, and necessitates further additions. Additions of excessive acid would result in the risk of iron being dissolved, and thus polluting the solution from which the copper sulphate has to be crystallised. The products of this treatment are insoluble residues chiefly consisting of iron oxide and lead sulphate, and a solution of practically pure copper and silver sulphates.

If the roasting has been imperfectly conducted, some cuprous oxide may be formed which will cause silver to be precipitated, and the insoluble residues may thus contain an undue proportion of silver. The residues contain anything from 750 to 1,000 oz. of silver, 12 oz. of gold, 3 oz. of platinum, and about ½ oz. of iridium, etc. In view of the good fluxing qualities of the iron oxide and lead sulphate, the residues are used as fluxing material for the making up of briquettes with poor sweeps, etc., for blast-furnace smelting.

Precipitation of Silver

After the roasted matte has all been digested in the weak acid, the remainder of this acid (which up till now has been maintained at 2%) is neutralised by adding copper scale. Instead of using water and acid as the solvent, there is usually some surplus acid which can be utilised, which comes from the direct acid-treatment of bought silver sulphides, and already contains some copper to be used up. The products from the acid-stirring vat are then filtered, either using a large wooden filter-press, or a centrifugal with copper basket, and lined with coconut matting. The insoluble residues are washed with hot water, and transferred to the briquetting plant. The liquors are run into large lead-lined vats, and exposed to the action of copper sheets. These latter consist of melted down copper materials containing silver, but which must be free from gold, etc.

This follows the Augustin process in detail.

The vats are kept heated by steam heat, and the process continued until the liquors are free from silver as confirmed by a test with common salt. In view of the value of the silver precipitate, filtering is not adopted, and when the treatment is completed, the liquors are settled and then run off, and further allowed to again settle for protracted periods. The copper sulphate is ultimately passed through a cloth filter prior to crystallising out. The silver mud is washed in water, and transferred to a small pressing machine whereby it is formed into brick shape. The bricks are then dried, and melted in crucibles under a little flux, and the product grained by pouring into cold water. The pressed bricks of silver precipitate contain well over 99% of silver, and the final melting in the crucible removes any traces of impurities, as the latter are readily fluxed off. The grained condition is a desirable form in which to have the silver, as it may be then weighed out with great accuracy for the making up of silver alloys.

The copper liquors from the filtered silver precipitate are transferred to a large evaporating vat, which simply consists of a lead-lined wooden vat heated by lead coils. Evaporation is conducted by the surfaces of the lead pipes, which in themselves are not good conductors of heat, but which allow of the liquor being slowly evaporated in large bulk. The addition of the copper scale reduced the free acid content to about 0·2%, and the evaporation is continued until the specific gravity, which is usually about 1·2 has been raised to 1·4. A hydrometer is used to test the specific gravity, and when the latter point has been reached the liquor is run into sheet lead vats, where it is allowed to lie for three days to crystallise out. The mother liquor is then used to assist in the solution of the roasted matte, until it has become too foul. A maximum is sometimes made of 350 grains of iron per gallon, and 300 grains of nickel per gallon, after which the copper is precipitated by scrap iron in the usual way.

The crystallised copper sulphate is chipped out from the lead vats, given a slight washing whilst being spun in the centrifugal, and then graded by passing through a trommel sieve.

As regards the size of the plant, the respective capacities until recently were as follows. About 10 cwt. of roasted matte were digested in the Hofmann stir vat which had a capacity for some 660 gallons. The vat for precipitating the silver on copper sheets held 740 gallons, and the evaporator vat had a capacity of 1,100 gallons. The lead vats in which the copper sulphate was allowed to crystallise out were twelve in number, each of a capacity of 300 gallons. Five well vats were required to contain the surplus weak acids, and mother liquor, etc., and the total capacity of these amounted to some 6,800 gallons.

A weekly charge of some eight tons of roasted matte can be handled in the above plant, which by manipulation of the crystallising out every three days, will allow of the use of 19 vats per week.

It is not necessary to press the silver precipitate into bricks and then melt under fluxes. An alternative method consists of simply drying the precipitate, and charging it on to the silver "test," or cupellation furnace, wherein all minute quantities of base metals are oxidised out. In some cases, the precipitated silver only shows from 80 to 90% of silver, but the feature of the process is that it is completely free from gold, or platinum, and hence need not be mixed with other silvers which would necessitate the subsequent electrolytic process—*i.e.*, the Balbach-Thum, or Moebius processes. By passing the matte through the ancient Ziervogal roasting system, and the Ottokar Hofmann wet process, all gold and platinum remain in the insoluble residues, which on being utilised as a flux for the briquettes of poor sweep and concentrate thus transfer these constituents to the blast-furnace lead. A simple and direct division is thus made, as the bulk of silver recovered by this means is directly precipitated by copper sheets, and need not be electrolysed.

The base metal constituents of the insoluble residue is some 50% of oxide of iron, 13% copper, 17% lead, and from nil to 3% of insoluble, The good fluxing qualities are apparent, as lead is present as the insoluble sulphate, and iron as oxide.

The process is conducted by unskilled labour throughout, and the only section requiring anything in the way of attention is the roasting. This is checked by taking samples every few hours and determining the soluble silver content using Volhards method.

The matte should show at least a 90% extraction of silver before passing on to the Hofmann process—*i.e.*, if the roasting has been properly conducted. Prior to taking the sample, the men at the roasting furnace make a rough test by stirring up a little of the roasted matte in hot water. Should the roasting only have converted the copper sulphide to Cu_2O, this would be serious to the economical working of the wet process, since what silver has been dissolved is liable to be

(*Continued on page 25.*)

Reducing Spalling on Nitrided Dies

By BERNARD THOMAS

In this Article the author discusses the spalling of nitrided dies, and offers suggestions to overcome difficulties which arise from the use of sharp corners and angles.

SO exhaustively has the subject of steel nitriding been dealt with in recent years that it would seem difficult to open up any really fresh angle which might claim for itself originality. That "spalling" of nitrided corners has been discussed previously is recognised, but the object of this article is to advance a few thoughts and suggestions for the amelioration of those corners and angles on nitrided parts which need to be sharp, but suffer by reason of "spalling" because of that same sharpness.

As far as the writer is aware, the particular aspects which follow have not been dealt with previously, except to a much lesser extent by the author himself elsewhere at an earlier date, and the data set forth herein represents an extended study of previous work.

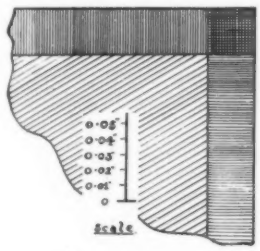


Fig. 1.

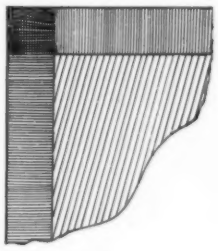


Fig. 2.

It is not claimed that the theories advanced are fundamentally correct, but it is felt that as their practical application has proved to the writer that their adoption reduces the tendency to spalling there is something in the idea beyond mere supposition.

Question of Design.

That the cleanliness of the actual nitriding process must take some of the blame for the occurrence of spalling is only too true. When the most intricate of shapes and acutest of angles can be nitrided with absolute satisfaction, free from distortion, scaling or quench cracks, it is only natural that users, particularly those who may be changing from non-gaseous case-hardening processes, should desire to exploit the possibilities of tool design to the fullest extent. It is, then, unfortunate that spalling should occur, but the remedy lies largely in the hands of the toolmaker, rather than in those of the nitrider.

Spalling originates from the effect of penetration occurring from two surfaces which run at an angle to meet at a corner, thus giving increased hardness with accompanying brittleness at the point which is already weakest Reference to Fig. 1 will make this point clearer. The shaded portion which occurs parallel to the outside surfaces is intended to represent the depth of nitride penetration. It will be noted on the corner where double penetration would occur.

Sharp Corners.

The first obvious move would appear to be to remove or reduce the sharpness of the corner effect. But this step is frequently deplored by the toolmaker on the grounds that a sharp corner is essential for the purpose involved. Doubtless, many persons still feel that, as they were in the habit of leaving sharp corners on the die steels used previously to the nitrided ones, the latter, being of greater initial cost, should surely be capable of withstanding similar treatment without any attempt at humouring But "humouring" of this character is only a means to an end, and a wise means to a long end, too, in most instances

Let the position be analysed more closely, however. Examine Fig. 1 as representing a right-angled corner of the edge of any die impression. As such, the corner would be left by most toolmakers as being reasonable to expect satisfactory service therefrom. Now take a look at Fig. 2. At first glance, most would say that here was a corner which would not be safe if left with such sharpness. It is, however, identical with Fig. 1, but drawn in a different position, and thereby creating an illusion. It would seem from this that we have grown to expect a right-angled corner to stand up in such work, but when that same corner is presented to us in an unusual manner, we are not quite so certain about it, which rather goes to show how near to impracticability in design it is possible to sail without realising it.

It is true that the old die steels were invariably left with beautifully sharp corners, but shall we examine what became of them ?

Figs. 3 is intended to represent the section of a typical die-sinking for a small forging which, let us suppose, requires sharp corners at the points marked A, in order to produce a forging of the desired shape. Without doubt, if such a die were nitrided spalling would quickly occur on those corners in question, and this would produce a very rough surface indeed on the resultant

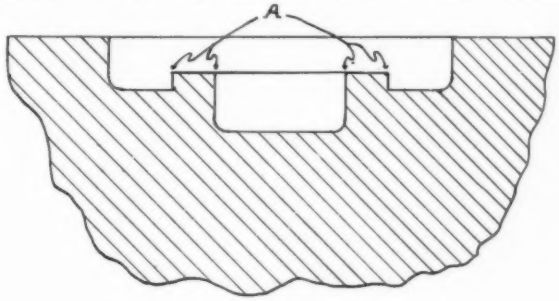


Fig. 3.

forging. But what of the die steels which are not nitrided ? In the first place, they would not spall, but with each succeeding operation a certain amount of wear would take place, which would soon result in the corners being blunted. This wear is almost always greater than that experienced on nitrided dies. The exact rapidity at which the blunting would occur would depend upon the nature of the die steel, an ordinary untreated carbon steel block giving probably the least service and either a nickel-chrome or nickel-chrome-molybdenum in heat-treated condition offering the longest resistance.

Comparisons of Service.

In the writer's experience the following is an average comparison of the service obtained from heavy press dies made in nitrided quality in relation to those of other qualities.

3·5	times	the life of	·60/·65%	Carbon	untreated.
3·0	,,	,, ,,	1%	Nickel	heat-treated.
2·1	,,	,, ,,	3%	Nickel-chrome	heat-treated.

It should be clear from these figures that because of the shorter total life obtained from dies which are not nitrided,

plus the early blunting of corners on same in addition, their actual period of service in first-class condition is relatively small. Further reference will be made to this later. The point of great importance is, however, that on all these types of dies, after only a part of their normal life has passed, the corners become slightly rounded, but, because the remainder of the impression or sinking is still in fair condition, the die is continued in service rather than resink or scrap for the blunted corners alone.

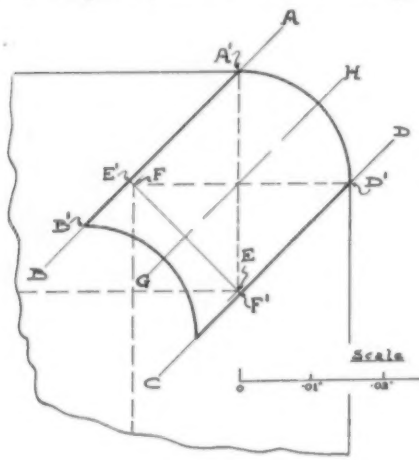


Fig. 4.

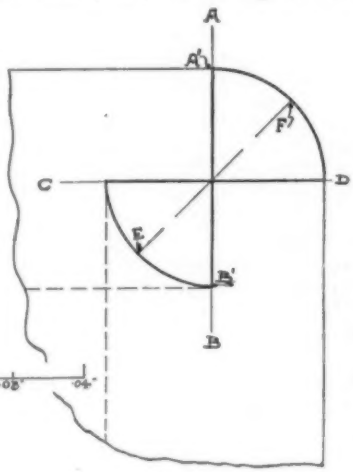


Fig. 5.

Similarly with the nitrided dies, only a very low percentage of the total life can be obtained free of any spalling in the presence of sharp corners, and, while the dies are rarely discarded solely for this reason, occurrence of the defect is detrimental to a perfect product. As already mentioned, spalling would not occur with the other types of steel, but any sharp corners subjected to work become quite rounded after 12 to 16% of the average expected life has elapsed, and for the remainder of their service forgings are produced which are rather inferior in finish to any produced in the nitrided dies. In fact, the last 10 to 15% produced are usually particularly bad by reason of the all-too-familiar "crococile" markings.

The above leads to the point that if 84 to 88% of the work produced from non-nitrided dies can be accepted after any sharp corners have ceased to exist, it is reasonable to suggest that the same should apply to the first 12 to 16% when the dies are new, and, correspondingly, as the 12 to 16% period only constitutes about 4 to 5% of the expected total life of a nitrided die for similar purposes, the obvious and sensible thing to do is to produce the nitrided die when new, complete with radiused corners, and so reduce considerably the tendency to spalling, thereby ensuring a greatly improved quality of production over a larger proportion of the expected die-life.

The writer suggests that such conditions obtain in very many instances in connection with the use of dies, and if users would only pause and consider quite frankly what the condition of the average die is like *after* about 20% of the expected life has transpired they would then, perhaps, be rather broader minded regarding what points really are essential when the die is new in view of what might have happened to those same features after the short period of service, and if the die is considered fit for further use the inference should be obvious.

Size of Radius.

Having arrived at the conclusion that one might just as well provide a radius on a nitrided die right from the very beginning, the next step is to decide exactly how much radius is really necessary for best results without overdoing matters. Of course, from the viewpoint of tool design, the less radius the better, so that one should start at a minimum rather than in the reverse direction.

The ideal radius would be one which at least equals, if not exceeds the actual depth of penetration attained by the nitrides, and in this respect $\frac{3}{32}$ in. would appear to be very suitable. Fig. 8 shows a corner section which bears a radius of $\frac{1}{32}$ in., while the depth of nitriding is shown as being ·030 in., a matter of ·0012 in. less. It will be noted that single penetration persists at all points and with such a radius little trouble from spalling under ordinary circumstances should be experienced. Unfortunately, however, it is not always possible to allow a radius of this size so that it becomes necessary to study other lesser ones.

Effect of Small Radius.

In considering smaller radii, it is of moment to study along what lines penetration occurs. Referring to Fig. 4, here we have a corner section bearing a $\frac{1}{64}$ in. radius, which is slightly more than half the depth of penetration which is again shown as being ·030 in.

It would appear natural to assume that the nitride penetration proceeds more or less rationally along what is to all intents and purposes, roughly, right angles to the outside surface. In consequence of this, in an instance such as depicted by Fig. 4, it would be taken for granted in most instances that from the curved surface of the rounded corner penetration would proceed along the area outlined by A–B–C–D, the distance from A^1 to B^1 being the same as from A^1 to E, which is the ·030 in. of what is being taken in these remarks as representing normal penetration from a flat surface. The distance from E^1 to F^1 is identical with that from A^1 to D^1, and the curve B–G–C is parallel to that A–H–D on the outside surface, so that such an area would appear feasible.

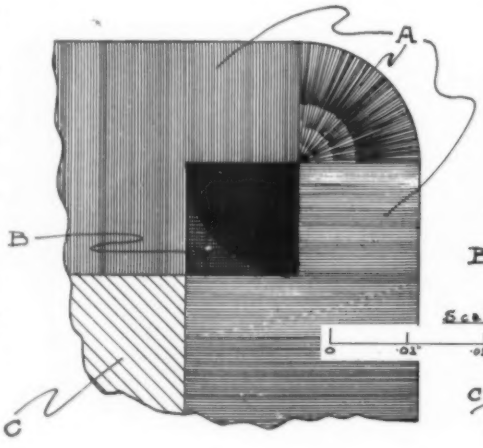


Fig. 6.

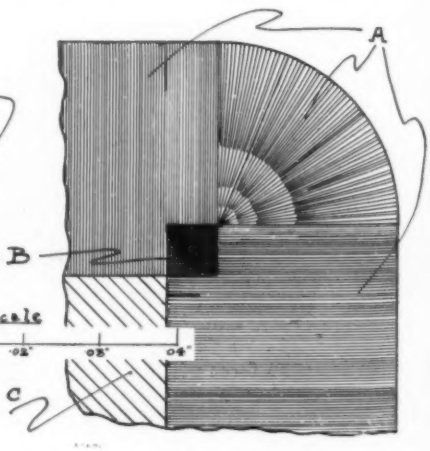


Fig. 7.

Penetration in the above manner would mean not only double, but treble effects in certain areas with the possibility of worse troubles from spalling than on a corner free of radius. But is this the correct theory of how penetration really occurs?

On the assumption that the case proceeds from a flat surface at approximately right angles, from the points A^1 and D^1 the nitrides would occur down to the points E and F, respectively. Proceeding round the radius from A^1 towards D^1 the penetration, still based at the nominal

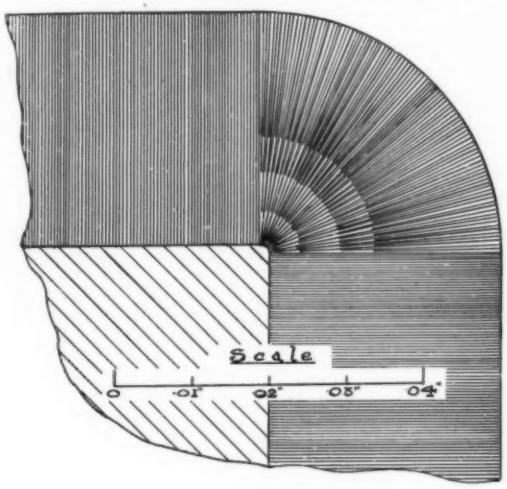


Fig. 8.

figure of ·030 in. for this purpose, is bound to proceed from E towards F. If A^1 to E is correct, then when the half distance along the A–H–D curve is reached the bottom of the penetration at this juncture must be ·030 in. from point H which gives point G on the B–G–C curve in the interior. Continuing along this basis, we arrive at D^1 which we already know must have penetration ending at F. It follows, therefore, that the penetration bottom must transcribe an arc from E to F touching at G *en route*. As the original curve A–H–D is $\frac{3}{64}$ in., or slightly more than half the penetration basis, it follows that the other from E to F must be of smaller radius in order to make the sum total of ·030 in. between the points H. and G.

Based on the above suppositions, Fig. 5 shows more clearly the suggested area of penetration which is considerably less than that in Fig. 4. Fig. 6 is similar to Fig. 5, the various areas, however, being shaded for clearer identification Areas marked A are those of single penetration, that of B is double penetration where the two outside surfaces other than the rounded corner have overlapped, while the black quarter-circle represents triple penetration where that emanating from the rounded corner has superimposed upon the double area last mentioned. C, of course, represents the original core of the body-metal.

Reducing Triple Penetration Area.

For an area of triple penetration to be so near the outside of a corner there is still rather too much risk of spalling under certain conditions, and it is necessary to endeavour to reduce this triple area as far as practicable.

So far we have considered a radius which exceeds penetration depth and which has no double, let alone triple area of penetration (Fig. 8) in addition to that last described in Fig. 6, which is half the Fig. 8 radius. Neither is entirely satisfactory for reasons already given, and this brings us to a consideration of Fig. 7. In Fig. 7 the radius on the corner is $\frac{1}{64}$ in. or ·0234 in. An increase of a mere half $\frac{1}{64}$ in over that in Fig. 6 would seem like splitting hairs, but reference to the shaded portions of Fig. 7, where the same lettering is employed for identification as in Fig. 6, will reveal the considerable reduction in area of triple penetration which the increased radius has brought about. Here this zone of potential weakness has receded not only to smaller proportions, but is farther removed in consequence from the outside surface. Actually, the radius employed in this instance is in round figures, 78% of the measurement of the nominal penetration depth basis, so that it should not occasion very much surprise that its use should have been so effective.

The writer has found in practice that this radius of $\frac{1}{64}$ in. can, in the majority of instances, be tolerated without undue average disfigurement of the work produced, and the effect of it is such that spalling, while not eliminated completely, is reduced to the lowest possible degree as is possible in conjunction with the requirements of a not too large radius on the corner to be rounded.

It is understood, of course, that where sharpness of corners is not necessary at all, the obvious thing to do is to be really liberal in radius allowances and exceeding the penetration depth should be aimed at wherever possible.

It is hoped that these remarks will encourage potential users to partake of the many advantages offered by nitrided dies, and that the suggestions put forward may help remove some of the difficulties encountered at present

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Treatment of Precious Metal Matte

(*Continued from page* 22.)

precipitated in the metallic state. Fortunately, the rough test quickly reveals this, since on stirring up with hot water and settling, the presence of the shining metallic silver will be readily apparent.

The roasting is continued until on testing no silver appears, when samples are taken to the laboratory for confirmation.

Should less than 90% of extraction of silver be recorded, the matte is simply returned for further roasting whereby the Cu_2O is converted almost whoolly to CuO, which is incapable of precipitating the silver, and hence the most desirable condition for the foregoing process. Rough material which does not pass through the 30-mesh sieve prior to passing on to the wet process, is usually set aside, re-ground, and re-roasted. The reason for this is that leady material may cause some imperfectly roasted matte to become enclosed in the form of lumps. Grinding is thus omitted after the roasting has been completed, and each lot is simply passed through a 30-mesh sieve, and the "roughs" returned for re-roasting. In some works, roasted matte whilst still hot was directly charged into the leaching vats, but with the Hofmann process, it was customary simply to introduce it in cold condition.

When the roasting has been continued for a week, the furnace is shut down and the hardened mass of roasted matter remaining on the bed of the furnace removed with the help of a "cutter" on the rotating arms, and also with the assistance of iron bars.

The bed of the roasting furnace slowly "makes up," *i.e.*, on weighing the caked mass, it will tend to increase from week to week, until a fresh bed is laid. The amount of matte necessitating cutting from the bed only reaches a few hundredweights per week with a fresh hearth. Should the matte be too rich in lead, and offer too great resistance to the stirring action of the arms, friction bolts become broken, and necessitate replacement.

The feature of the wet extraction process, and all success which attends it, almost entirely depend on following the directions given by Hofmann. These consist of never exceeding the 2% limit of sulphuric acid which practically prevents any iron passing into solution, and introducing the roasted matte in a slow steady stream. The products of the wet process are about eight tons of copper sulphate, and from 4,000 to 6,500 oz. of silver precipitate per week, but the capacity of the plant may be increased to work larger tonnages should such a demand arise.

Although the above process is widely used to-day it is handicapped by the fact that no appreciable nickel content can be tolerated in the raw materials accepted for the work.

The Mersey Tunnel

The Remote Controlled Ventilating System

IT will be remembered that the Mersey Tunnel was opened by His Majesty the King on July 18, 1934, and that in our issue for June, 1934, the construction of this tunnel was discussed, in which reference was made to the ventilating system. At that time, however, the control room was only partially constructed, but in March last the temporary arrangements were superseded and the fully equipped central control room was put into commercial operation, so that it is now possible, by the courtesy of the Mersey Tunnel Joint Committee, to present additional information on this important feature. Before doing so, some of the results experienced in the first year's working of the tunnel may be mentioned—viz., against an estimated number of vehicles of 1,350,000 the recorded number was 3,002,362, and against an estimated revenue of £135,000 the actual revenue was £250,143 9s. 10d.

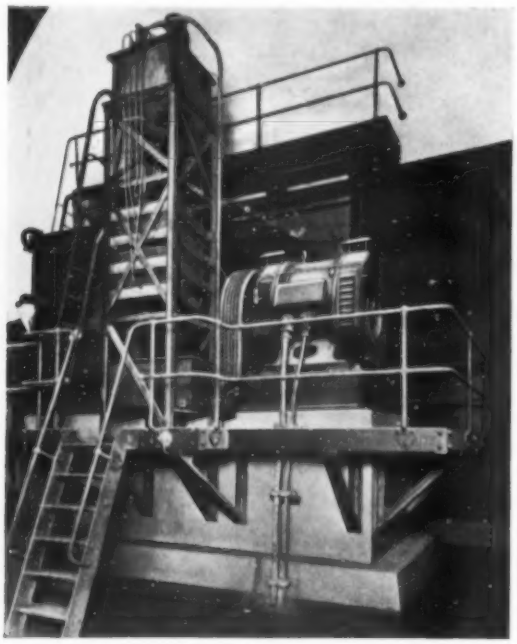


Fig. 1.—Showing a typical fan unit.

It may be recalled that for the withdrawal of used air from the tunnel roadway, and to blow in fresh air via-ducts formed under the roadway and passages under the kerb at each side of the road, six ventilating stations are provided, three being situated on each side of the river.

The ventilating stations are equipped, in all, with thirty motor-driven fans, the fans having impellers which range from 7 ft. 6 in. to 28 ft. in diameter, and from 3·35 to 23·75 tons in weight, and being driven by Metrovick-type R S squirrel cage motors totalling 5,140 h.p. in capacity, and ranging in output from 30 h.p. at 720 r.p.m. to 430 h.p. at 735 r.p.m. The motors are supplied with 3-phase 50-cycle energy at 400 volts. To ensure the utmost reliability, the fans and motors are arranged in pairs, with two fans connected to the same duct, one set serving as a stand-by to the other, and it being made impossible to run both fans at the same time. Moreover, to meet widely varying conditions of traffic density and atmosphere, great flexibility of output is arranged for. Every motor has two distinct windings on the stator, giving alternative speeds and outputs. Also in each pair of motors the low-speed ratings are varied, so that from every pair three alternative high-efficiency ratings are available, while still further adjustment of output can be made by varying the speed of the fan by means of a hydraulic coupling provided in every unit between the motor and the reduction gear through which the fan is driven.

An illustration showing a typical fan unit is given in Fig. 1, in which the hydraulic coupling is shown protected by a perforated screen to the left of the motor, while in front of the reduction gear is shown a steel framework carrying a gravity supply tank, a drainage tank, and four coolers, all used in connection with the supply of liquid to the coupling.

The actual starting of the fan motors is done by electro-magnetic contactor control gear, which is mounted together with protective relays in separate sheet-steel cubicles for each motor. Across the top of each cubicle are placed two ammeters, for the low-speed and high-speed motor windings respectively, a voltmeter, a fan speed indicator, lamps which indicate whether the motor is running on its high or low-speed winding, and further lamps which indicate the position of the weir of the hydraulic coupling. It may be mentioned that on the plinth of each fan motor a switch is provided to prevent the starting of the motor while men are working either on the motor, the coupling, or the fan.

All signals and control impulses sent from or received in the central control room are transmitted through direct pilot wires in multi-core cables, such impulses being received by interconnecting relays. The interconnecting relays are sensitive instruments which require only a small fraction of an ampere for their operation. They serve to actuate either auxiliary relays or auxiliary contactors, by which either indicating lamps are caused to glow or auxiliary motors or the main starting motors are controlled.

The Central Control Room.

Before describing the central control room, reference must be made to metering and indicating panels which are placed in each ventilating station. Each metering panel is equipped with separate integrating watt-hour meters for each of the high-voltage supply feeders, these meters being summated by a third integrating meter, which is fitted with a maximum demand indicator and a 30-min. interval time switch, and the readings of which are transmitted for further summation to the central control room.

In the central control room, two control boards and an 11-panel semi-circular recorder board are placed. For each ventilating station a control panel is provided, flanked on both sides by either two or three separate panels according to the number of fan units in the station referred to. Each of the central panels for the four 6,000/6,600-volt stations is equipped with a mimic diagram containing red, green, and white lamps which are connected with the type K high-voltage circuit-breakers, and glow when the circuit-breakers in question are closed, normally opened, or automatically tripped respectively. The panels also contain two high-tension voltmeters, a C O indicator, and alarm lamp with re-setting switch, also a visibility indicator, and various signalling relays and signalling circuit fuses.

Control can be effected either from within each ventilating station or from the central control room. The operating engineer in the control room at King George's Dock is provided with complete information regarding the rate of air flow, the proportion of carbon monoxide, the visibility of the atmosphere as affected by the presence of smoke or fog, and the number of vehicles entering and leaving the tunnel. He has continuous indications showing the position of the high-voltage circuit-breakers in the ventilating stations, and is able to open and close circuit-breakers and start or stop or regulate the speed of any of the ventilating units.

It should be stated that all the motors, transformers, and switch and control gear for the tunnel ventilating equipment are of Metropolitan-Vickers manufacture, and that the number of pilot wires is reduced to an economic minimum by a Metropolitan-Vickers Company system of graduated current impulses which allows a number of different signals to be sent over the same line.

Recent Developments in Materials, Tools and Equipment

The Magnetic Separation of Minerals

MAGNETIC separation lends itself readily to the treatment of minerals of differing magnetic permeability which are of approximately the same specific gravity, and cannot for that reason be separated by gravity concentration methods. The frequent association of wolfram with cassiterite is a case in point. Their specific gravities are so nearly alike that gravity separation is impossible, but as wolfram is feebly magnetic, its removal from the non-magnetic cassiterite can be effected by the use of suitably designed high-intensity electro-magnets. Tantalite can be separated from cassiterite in a similar way. The same principle may also be applied to the separation of strongly magnetic minerals, such as magnetite, ilmenite, roasted pyrite and marcasite, etc., from substances of lower magnetic permeability.

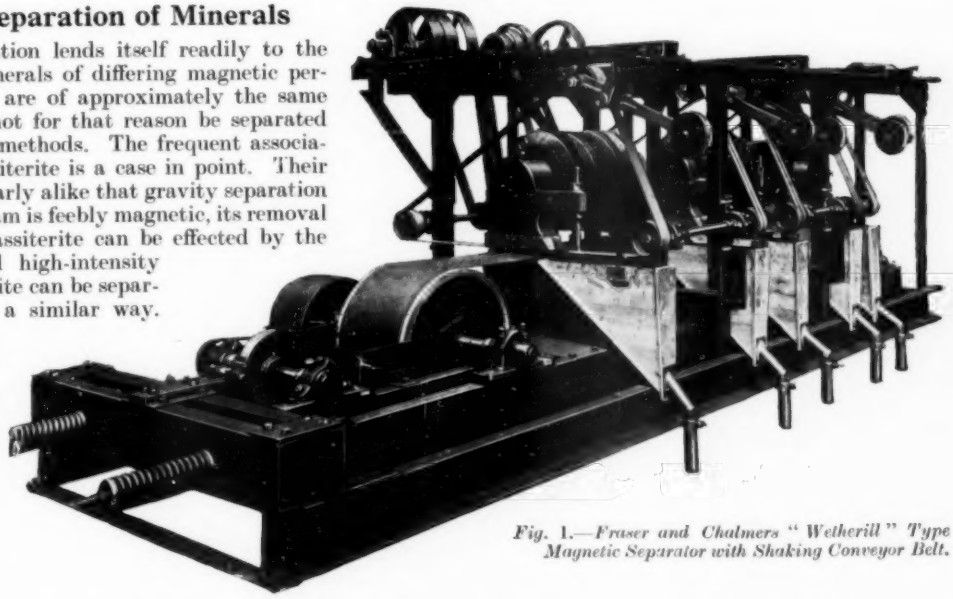


Fig. 1.—Fraser and Chalmers "Wetherill" Type Magnetic Separator with Shaking Conveyor Belt.

For separations such as those mentioned above, it is claimed that the best results can be obtained with the "Wetherill" type magnetic separator, working on the cross-belt principle, which has a wide range of adjustments giving it great flexibility in operation. "Wetherill" type separators are manufactured by the Fraser and Chalmers Engineering Works of the General Electric Co., Ltd., at Erith, Kent, where plant and machinery for every branch of the mining and metallurgical industries have for many years been manufactured for export to all parts of the world.

Operating Principle.

The basic principle upon which this magnetic separator works depends upon the fact that if a particle of mineral or similar substance which has a permeability greater than air is presented to a magnetic field it will tend to move towards the strongest portion of the field. For successful separation, therefore, not only must the field be strong or have a large number of magnetic lines of force per unit of area, but the lines must converge to some point, which in the case of this machine is the edge of an upper tapered pole. This pole is placed a short distance above a lower wide pole, and between the two a conveyer belt carries a layer or bed of the material to be separated. The magnetic particles jump out of the moving bed towards the upper pole, and adhere to the underside of a cross belt which runs at a fairly high speed just under the pole edge at right angles to the conveyer belt. The momentum acquired by the particles from the cross belt is sufficient to fling them out of the magnetic field into a receiving hopper. The machine may have one, two, or three pairs of such poles, a similar separation taking place at each one. The second and third pairs are arranged to have successively stronger fields than the first in order to remove material of lower magnetic susceptibility or permeability. The non-magnetic particles are discharged over the conveyer belt tail pulley.

The latest model of Fraser and Chalmers' "Wetherill" type magnetic separator with shaking conveyer belt and a steel frame is shown in Fig. 1. The machine illustrated has two two-pole coil-wound magnets and two cast-iron blocks underneath with poles corresponding to those above. An auxiliary magnet consisting of a narrow iron bar connected through a strip of iron with the first coil-wound magnet is placed at the feed end for removing tramp iron; it has no corresponding lower pole.

The conveyer belt is mounted on a frame which is separate from the main structure. A cam mechanism gives this frame a jerk at intervals which are so timed that the material on the belt is turned over during its passage from one pair of poles to the next to expose fresh particles. The underside of each upper pole is tapered, as already explained, and the edge is brought to a point on the side nearer the hopper to help in throwing the magnetic particles clear of the conveyer belt.

Whatever the type of separator, each magnet consists of two upper poles with exciting coils between them, and corresponding lower poles under the conveyer belt, the strength of the field depending on the number of coils and the current passing through them. For separating feebly magnetic material, both upper and lower magnets are usually provided with exciting coils in order to produce magnetic fields of maximum strength. When fields of comparatively low intensity are sufficient to effect separation, the lower magnets consist of plain cast-iron blocks without exciting coils. The arrangement of the magnets and the strengths of the fields depend on the nature of the material to be treated, and can only be determined by actual tests.

The depth of the bed of material on the conveyer belt can be regulated by means of the automatic feeder, and the belt itself is provided with a variable speed mechanism fitted to the drive. These two adjustments, together with the field regulation mentioned, give this separator great flexibility in operation, and enable it to be run at maximum capacity under varying conditions.

Preparation of the Material.

The material to be treated must be quite dry and should be crushed fine enough to free the magnetic particles. The operation of crushing needs considerable care, since unnecessary fines are to be avoided. Should the magnetic product separated consist of "chatty" material—*i.e.*, magnetic particles with non-magnetic mineral still attached, it will have to be recrushed and retreated. In certain circumstances it may be economical to perform the separation in this way rather than crush the whole of the material to the finer size before commencing the separation.

Magnetic separation may conveniently be preceded by

one or more screening operations, the limits of the sizing depending on the class of material to be treated. A sized feed is recommended, but there are cases when it is not possible, such, for instance, as the removal of particles of iron from china clay, which is extremely difficult to screen in any event. The method adopted in this case is to use enough power to lift all the magnetic particles plus a proportion of the non-magnetic powder (by entrainment), the loss of clay being of small importance compared with the elimination of the iron, which will otherwise discolour the clay when fired.

Performance.

The output obtainable from the several sizes and types of separators depends on the size and nature of the material to be treated. In general, the coarser the particles and the closer the sizing, the higher will be the output.

The capacity of the machines is limited by the conveyer belt. A width greater than 18 in. is not practicable owing to the difficulty of separating the magnetic particles from a wider belt without dragging non-magnetic material with them by mechanical entanglement. On the other hand, it is not advisable to use a belt narrower than 6 in., owing to the harmful effects of magnetic leakage. The best width of belt for normal purposes is 15 in., and this size is recommended in most cases.

Under the most favourable conditions, the 15-in. separator may take a feed of 2 tons per hour of material which has all passed a 10-mesh screen, while a difficult separation of fine mineral may reduce the capacity to 2 cwt. or 3 cwt. per hour. The capacity and specification of a machine for a particular purpose can only be determined by actual tests on the material to be treated. It is understood that Fraser and Chalmers' Engineering Works are prepared to carry out such tests, to specify and construct the type of separator best suited to the work, and, if required, to design and supply complete concentration plants and erect them ready for operation.

A New Oil-fired Heat-treatment Furnace

THE influence of heat upon the quality and cost of nearly all manufactured products necessitates efficient methods of heating and cooling effecting the conduct of heat-treating operations. The ideal sought in practice is attained only by a proper combination of the furnace and operative. With better furnaces, approaching the efficiency of the machine tool, and better methods of heating, there is no question of the possibility of improving the quality and reducing the relative cost of heat-treated products. The production and manufacture of "Adamite" rolls, in which heat-treatment plays a very important part, is an example, and special oil-fired furnaces have been designed and installed for this purpose.

Many designs of furnaces were submitted, and after careful consideration of all the factors involved in the treatment of these rolls, the contract was placed with James Howden and Co., Ltd., who have an extensive experience of all types of furnaces, including stamping, annealing, case-hardening, shipyard bar and plate furnaces, etc. Fundamentally, the treatment of rolls consists of two phases: the heating phase and the cooling phase, but whether the phase being considered is one of heating or of cooling, it is concerned with a suitable correlation of the basic factors of temperature and time.

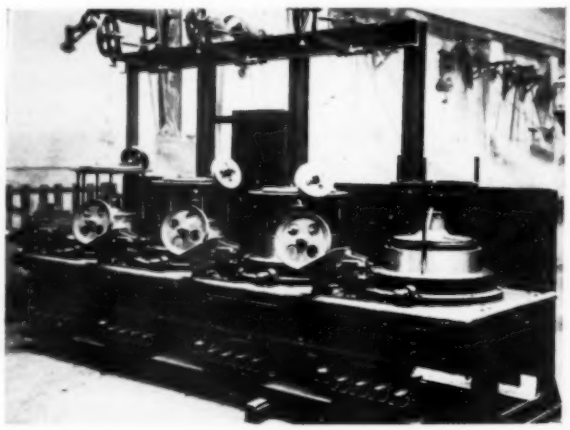
This new furnace has a number of special features designed to meet the special requirements and cycle of heat-treatment for rolls. A combustion chamber is arranged along both sides, as will be noted in the illustration shown on page 3, from which the hot gases pass into the heating chamber to ensure a gradual temperature rise on the rolls by radiant heat Slow, careful, and uniform heating is desirable, and after a soaking period at a temperature below the critical range, the heating chamber is brought to its final temperature by bringing into action a further set of burners firing direct into the chamber, and so arranged that direct impingement of hot gases on the rolls is avoided.

The whole oil supply system is controlled by means of electrically operated cut-outs, controlling from storage to auxiliary tanks, and the supply to the burners has a thermostatic control whereby the operator can see from the temperature recorder equipment fitted the exact rise and ultimate temperature. The method adopted has the advantage of avoiding risks due to local or over-heating.

The furnace is capable of dealing with a charge up to 100 tons, and it is so designed that it can easily be converted for the use of either producer or town's gas at short notice. It is claimed that the oil consumption per ton of charge is most satisfactory, and James Howden and Co., Ltd., are erecting a further set of these furnaces at the works of Messrs. Tennent, Ltd.

A Four-unit Wire Drawing Machine

THE photograph reproduced illustrates a four-unit non-slip machine for drawing down mild steel or equivalent metal from rod. Each unit has individual motors arranged for foot control. The machine is built up in single units, all of which are interchangeable excepting the gear ratios; this arrangement permits the installation to be built up from any reasonable number of units with varying speeds, according to the metals to be drawn and arranged for dry or wet lubrication. Electrical control gear with adequate



Four-unit non-slip wire drawing machine.

braking is arranged on simple but fool-proof lines, and the gears are of helical formation with a pump and dry sump system of lubrication. The blocks, which are of 22-in. diameter, are water-cooled, which method is also employed for the cooling of the dies. The main bearings for the gears, as with the bearings of the vertical spindles of the blocks and the vertical spindles of the countershaft, are equipped with Timken tapered rollers, to ensure longevity and constant precision.

The machine illustrated is to be a standard product by Brookes (Oldbury), Ltd., and is capable of drawing down from 5-gauge mild steel rod to 13-gauge wire in four drafts, finishing at 750 ft. per min. with a total consumption of 50 to 55 h.p.

Direct Retrieving of Iron

AT the experimental plant of Komprovosstal in Ivanovo successful experiments have been concluded in the direct retrieving (without the blast-furnace process) of iron from titano-magnetite ores with a content of vanadium. The plant has already turned out several tons of porous iron. This is being sent to the Spetzstal plant to try out (on an industrial scale) whether it is possible to produce high quality steel from it with the simultaneous utilisation of the vanadium content in the metal.

Recent Developments in Steel Frame Construction

"Although the first steel section was produced only about fifty years ago, the great contribution which steel has made to the constructional arts in this comparatively short time represent a most remarkable achievement," said Mr. C. J. Kavanagh, O.B.E., Director, British Steelwork Association, at a recent meeting of the Institute of Engineers and Shipbuilders in Scotland, at which he discussed steel frame construction, brief reference to which is given in this article.

EXCEPT for a few noteworthy examples in the early days of steel construction, the application of the new constructional technique in steel was more in evidence in bridge design and in naval architecture than in building. It occasions some astonishment that in spite of the very obvious lessons provided by bridge construction in the easy mastery over loads, and by naval architecture in its efficiency of space-planning (the essence of all commercial architecture), the vast potentialities of steel in building were not more rapidly developed. It is said that the erection some 40 years ago of the Eiffel Tower, which was certainly the precursor of the American skyscraper, met with the most inflexible opposition on the part of authority, but the faith—or, rather, the mathematics—of M. Eiffel ultimately triumphed.

This tardy appreciation of the potentialities of steel as a constructional medium for commercial building was principally due to our training in the traditional methods of building. Steel in building construction has been obliged to operate within the limits of old and often very obsolete legal enactments, and has, in consequence, shown a stunted growth compared, for example, with achievements in ocean liners, aircraft, or motor transport, where the designer has been quick to perceive the potentialities of steel construction and quick (by reason of international competition) to apply them. Fortunately, these legislative difficulties are now in course of disappearing. The new Code of Practice which evolved in 1932 from the recommendations of the Steel Structures Research Committee of the Department of Scientific and Industrial Research, represented a considerable advance. It was adopted by the London County Council and concurrently by the British Standards Institution, which embodied the recommendations with less stringent fire-encasing requirements in a British Standard specification.

While it is true that developments in steel frame technique have given us the most apt method of taking charge of the loads and forces acting upon a building, thus reducing the engineering problems to simplicity with security, they have also given us the opportunity to build in an entirely new and organised fashion. From another aspect steel has exerted an immense influence on architecture; its introduction in building has undoubtedly revolutionised the space-planning with which all commercial architecture is primarily concerned. It has eliminated the extreme wastage of usable space common to brick, stone, and reinforced concrete construction; this is particularly evident on valuable sites of city buildings, where no less than 25% of the ground-floor space is taken up by enclosure and division walls. The "floating partition" has given the utmost fluidity in space planning.

Comparisons have been made in the past between steel and reinforced concrete, and comparisons will continue to be made in the future, but on the item of economy no engineer will decide without a careful analysis of all the factors involved. Too often are important items overlooked or omitted, and where the comparison is confined to individual units the impressive display of figures is really worthless. Even to attempt to compare one complete structure with another is almost as presumptuous as the comparison of one unit of construction with a similar unit constructed of an alternative medium, without reference to the aspects of construction time, utility, maintenance, and the future value of the finished building.

The advent of the steel frame has completely changed our outlook on building organisation. It has transformed it from an almost haphazard manual operation with barricades of timber scaffolding and a general confusion of trades, to something approaching an industrial, or mechanised, process. Speed and sequence have given the whole process a new emphasis, and building may now be regarded as falling into three main categories—organisation, construction, and materials. Of these, the results of organisation, seen in the introduction of the "time and progress schedule," are perhaps the most spectacular, whence the whole building programme, based upon co-ordinated team work, of which the rapid delivery and erection of the steelwork is the pivot, is reduced to a work of precise and rapid assembly.

With the completion of the steelwork, the laying of floors and roof becomes a simple process giving large expanses of horizontal platforms, upon which the subsequent building operations can proceed irrespective of weather conditions. Mass production and the standardisation of parts have a definite place in modern architecture without in any way involving a surrender, or loss, of æsthetic values, and the steel frame, by disposing of the loads in the most direct and unobstrusive manner, simplifies the whole building operation from the foundations to the final installation of the accessories.

Finally, Mr. Kavanagh pointed out, steel construction has given to the "commodity" value of a building its proper significance for the first time. Hitherto, little attention has been focussed upon this matter, but the rapid changes which now characterise business and industrial life compel the building owner to study the future value of his building. His primary safeguard in this is the type of construction, and it is here that the steel frame, by entirely eliminating the cumbrous and massive walls and partitions and giving a thoroughly adaptable structure, has made such a vital contribution to the economies of building. Adaptability is of prime importance if a building is to retain a good leasing or market value, by being capable of easy and cheap transformation to the changing requirements of a neighbourhood, of commerce, or of trade.

As for the future of steel construction in building, where shipbuilding leads, commercial building will eventually follow. Shipbuilding has for many years adopted high elastic limit steels, such as "Martinel" and other high tensile steels, reducing the sizes of scantlings, increasing the accommodation, and reducing the weight-tonnage ratio. High tensile steel of 50% greater carrying capacity is only now being used in building construction. The use of welding, an established practice and an everyday feature in ship construction, is looked on, so far as building is concerned, as a new technique. It must always be so; shipbuilding is an industry subject to the onslaught of severe competition, and the latest scientific developments in construction must ever be pressed into service; hence it prepares the way, and ultimately other and more sheltered industries benefit.

Business Notes and News

Railway Works Programme

The Government have announced proposals designed, through the medium of a loan, to enable the railway companies to put in hand a programme of works estimated to cost about £30,000,000. The object of the loan, which is similar in nature to that created for the London Passenger Transport Scheme, is to enable the railways to avail themselves of the present low rate of interest so that they may undertake certain approved works of public advantage, which they would not otherwise have undertaken at this time. The railway companies are in full sympathy with a policy intended to relieve present unemployment, and after careful consideration of the additional immediate burden on their finances and the possibility that the execution of the works at a time when they could no longer be delayed would ultimately involve heavier expense, have readily entered into the proposals of the Government. The works included in the lists approved by the Government will place the companies in a position to carry increased traffic with efficiency, and will, it is considered, ultimately yield a profit to the shareholders; but it will be some time before works of this character may be expected in all cases to show full fructification, and for this reason the provision of a loan at a lower rate of interest than otherwise obtainable was an essential condition of the works being undertaken.

Recent years have shown a steady growth in the passenger traffic carried by the railway companies, both for business and for recreation purposes. If this growing traffic is to be handled with the speed and efficiency which are becoming more necessary every year, it is of the highest importance that the running facilities and station equipment on main lines and important branches should be of the most up-to-date character. Works of this kind, coupled with the improvement of signalling on main lines and at busy junctions, form therefore a large part of the programmes of the approved new works. The same object has influenced the companies in their schemes for the extension of electric traction, both on main lines and in suburban areas. The provision of more powerful and efficient locomotives, of more numerous and more comfortable carriages are of great importance to meet the changing traffic conditions.

The completion of these works will place the railway companies in a much more favourable position to provide a speedier, more adequate and more efficient train service for accommodating the increasing public requirements for all classes of traffic. Fuller details of the approved works are not yet available.

Headgear for S.A. Copper Mines

The illustration reproduced is of the Selkirk headgear manufactured by Sir William Arrol and Co., Ltd., for the Mufulira Copper Mines of South Africa. This headgear will wind both skip and cage, which descend to the maximum mine depth of 2,700 ft., at speeds of 1,500 ft. per min. up to 1,600 ft., and thereafter at 2,500 ft. per min. The skip alone weighs 22,000 lb. and will hold 22,000 lb. of ore. The cage is designed to accommodate 136 men, whose total weight is computed at 21,000 lb., or alternatively will hold material up to a weight of 24,000 lb.

Selkirk headgear for South African copper mines, manufactured by Sir William Arrol & Co., Ltd.

As both skip and cage are operated on the balance weight principle, the headgear, which is mounted on eight 2-row Timken tapered roller bearings of 10 in. × 17·5 in. × 6·5 in. dimensions, will support the possible deadweight of two skips or cages, complete with the materials they contain, or a maximum of 90,000 lb.

Darwins new branch office and showrooms in Birmingham.

Oil from Coal: Scottish Move

For some time past several Scottish business men have been working quietly with the idea of extracting every product of value from coal without waste, such as oil, pig iron, tar, and cement, and large amounts have been spent on research work. According to Sir Godfrey Collins, Secretary for Scotland, a company, with an influential backing, is being formed with capital privately subscribed to take over works near Glasgow. The works include blast-furnaces with the necessary equipment and accessories, facilities for the manufacture of oil, pig iron, tar, and cement, and an electric generating station for supplying all the power required. Included in the purchase are several miles of main line and other sidings in the works.

Raw materials to be used are indigenous to Scotland, and for all the products to be manufactured there is an extensive and expanding market. In addition, the concern will develop the very large coal and iron ore deposits which exist within a few miles of the works in Lanarkshire. The production of oil from coal will be a very important part of the business, and the company is acquiring a very large deposit of torbanite iron ore containing a high proportion of oil. The existing works are ready to start as soon as arrangements have been completed, and they will find employment for a large number of men, starting with about 750 and gradually increasing. This should start a new era in coal and oil industrial development in Scotland.

The Mica Industries in Canada

Sales of mica from Canadian mines last year totalled 998 tons, valued at $97,071, as compared with 944 tons ($49,284) in 1933. Production last year was, as usual, in Quebec, Ontario, and British Columbia. A very pronounced increase took place last year in exports of Canadian mica, the total value reaching $117,802, as compared with $46,213 in 1933. The increase in exports of thumb-trimmed (and rough-cobbed) mica to the United Kingdom is especially worthy of note in that they show an increase from 3,900 lb., valued at $2,027 in 1933, to 147,000 lb., worth $60,635 in 1934. All exports of scrap mica and waste went to the United States in 1934, and were somewhat less in both quantity and value than for the preceding year. Exports of splittings to the United States and United Kingdom markets increased, with by far the greater proportion of the shipments going to the former country.

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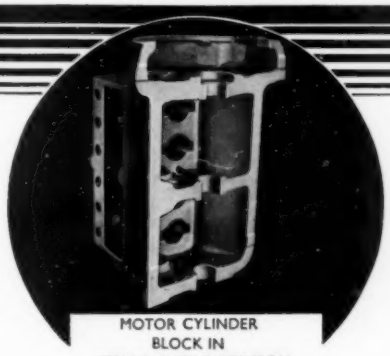
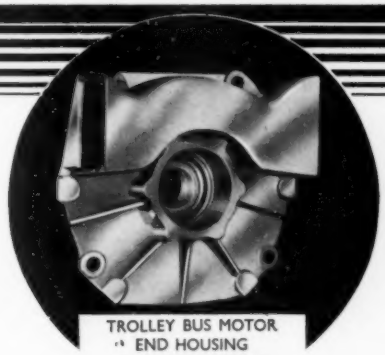


MOTOR CYLINDER BLOCK IN STERLING CYLINDER IRON

MOTOR CYLINDERS IN STERLING CYLINDER IRON



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MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£79	0	0
Chinese	68	0	0
Crude	36	0	0

BRASS.

Solid Drawn Tubes	lb.	9⅜d.
Brazed Tubes	„	11½d.
Rods Drawn	„	8⅜d.
Wire	„	7⅞d.
*Extruded Brass Bars	„	4½d.

COPPER.

Standard Cash	£35	0	0
Electrolytic	39	0	0
Best Selected	38	5	0
Tough	37	15	0
Sheets	68	0	0
Wire Bars	39	7	6
Ingot Bars	39	7	6
Solid Drawn Tubes	lb.	10½d.	
Brazed Tubes	„	10½d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	3	3
‡Ferro Tungsten	„	0	3	0
NOMINAL — Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2–4% Carbon, scale 11/- per unit	ton	29	15	0
4–6% Carbon, scale 7/- per unit	„	22	7	6
6–8% Carbon, scale 7/- per unit	„	21	12	0
8–10% Carbon, scale 7/- per unit	„	21	12	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	33	10	0
Guar. max. 1% Carbon, scale 12/6 per unit	„	36	5	0
§Guar. max. 0·7% Carbon, scale 12/6 per unit	„	37	5	0
‡Manganese Metal 97–98% Mn.	lb.	0	1	2
‡Metallic Chromium	„	0	2	5
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	„	8	17	6
45/50% basis 45%, scale 5/- per unit	„	12	5	0
70/80% basis 75%, scale 7/- per unit	„	17	17	6
90/95% basis 90%, scale 10/- per unit	„	28	17	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	12	17	6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	20	0	0
§ Ferro-Molybdenum, Molyte	lb.	0	4	6
§ Calcium Molybdate	„	0	4	2

FUELS.

Foundry Coke—				
S. Wales	—	1	5	0
Scotland	—	1	8	0
Durham	0 19 0 to	1	2	0
Furnace Coke—				
Scotland	—	1	5	0
S. Wales	—	1	0	0
Durham	—	0	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£56	10	0
*Commercial Ingots	42	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9
*Cored Bars	„	0	0 11

LEAD.

Soft Foreign	£17	19	0
English	20	0	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	10	10	0
Best Bars	10	2	6
Common Bars	9	5	0
Lancashire—			
Crown Bars	9	12	6
Hoops £10 10 0 to	12	0	0
Midlands—			
Crown Bars	9	12	6
Marked Bars	12	0	0
Unmarked Bars from	7	5	0
Nut and Bolt Bars £7 10 0 to	8	0	0
Gas Strip	10	12	6
S. Yorks —			
Best Bars	10	15	0
Hoops £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9½d.
*Cored Bars	„	11½d.
†Strip	„	11½d.
†Sheet to 10 W.G.	„	11⅜d.
†Wire	„	1/0½
†Rods	„	11½d.
†Tubes	„	1/1⅜
†Castings	„	1/-

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	13	6
Foundry No. 1	3	16	6
„ No. 3	3	13	0
N.E. Coast—			
Hematite No. 1	3	11	0
Foundry No. 1	3	12	6
„ No. 3	3	10	0
„ No. 4	3	9	0
Silicon Iron	3	10	0
Forge	3	9	0
Midlands—			
N. Staffs Forge No. 4	3	11	0
„ Foundry No. 3	3	15	0
Northants—			
Foundry No. 1	3	15	6
Forge No. 4	3	8	6
Foundry No. 3	3	12	6
Derbyshire Forge	3	11	0
„ Foundry No. 1	3	18	0
„ Foundry No. 3	3	15	0
West Coast Hematite	4	6	0
East „ „	3	11	0

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron Kr. 105
Billets Kr. 240-310 £12 7 6-£16 0 0
Wire Rods Kr. 290-340 £15 0 0-£17 10 0
Rolled Bars (dead soft) Kr. 200-220 £10 6 0-£11 7 0
Rolled Charcoal Iron Bars Kr. 290 15 0 0
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Converted at £1 = Kr. 19.40 approx.

SCRAP METAL.

Copper Clean	£29	0	0
„ Braziery	26	0	0
„ Wire		—	
Brass	19	0	0
Gun Metal	27	0	0
Zinc	9	0	0
Aluminium Cuttings	72	0	0
Lead	15	15	0
Heavy Steel—			
S. Wales	2	17	6
Scotland	2	10	0
Cleveland	2	12	0
Cast Iron—			
Midlands	2	7	6
S. Wales	2	14	0
Cleveland	2	12	0
Steel Turnings—			
Cleveland	1	17	6
Midlands	1	15	6
Cast Iron Borings—			
Cleveland	1	7	6
Scotland	1	17	6

SPELTER.

G.O.B. Official		—	
Hard	£13	10	0
English	17	7	0
India	14	15	0
Re-melted	15	10	0

STEEL.

Ship, Bridge, and Tank Plates			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	8	10	0
„ „ (Marine) „		—	
„ „ (Land), N.E. Coast	8	10	0
„ „ (Marine) „	8	17	6
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	10	0
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £6 17 6 to	7	2	6
Medium Basic £6 12 6 and	7	0	0
Soft Basic	5	10	0
Hoops £9 10 0 to	9	15	0
Manchester			
Hoops £9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ⅛ in. to ¼ in.	„	3d.
Under ¼ in. to 1/16 in.	„	1/-
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅛ in.	„	3d.
„ „ ⅛ in. × ¼ in.	„	1/-

TIN.

Standard Cash	£237	10	0
English	238	10	0
Australian	239	5	0
Eastern	227	0	0

Tin Plates I.C. 20 × 14 box 18/2

ZINC.

English Sheets	£24	10	0
Rods	29	5	0
Battery Plates		—	
Boiler Plates		—	

*McKechnie Brothers, Ltd. Nov. 14 † C. Clifford & Son, Ltd., Nov. 14 ‡ Murex Limited, Nov. 14

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices ex warehouse, Nov. 14